Vol. 4 DECEMBER, 1921 No. 12

Journal
—OF THE—
American Ceramic Society

A Monthly Journal devoted to the Arts and Sciences Related to the Silicate Industries

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Published Monthly by the
AMERICAN CERAMIC SOCIETY
Publication Office: 211 Church St., Easton, Pa.

Eight Dollars per Year. (Foreign postage additional.) *Single Numbers, Seventy-five Cents*

Entered as second-class matter, July 15, 1918, at the postoffice at Easton, Pa., under the Act of March 3, 1879.

Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized August 16, 1918.

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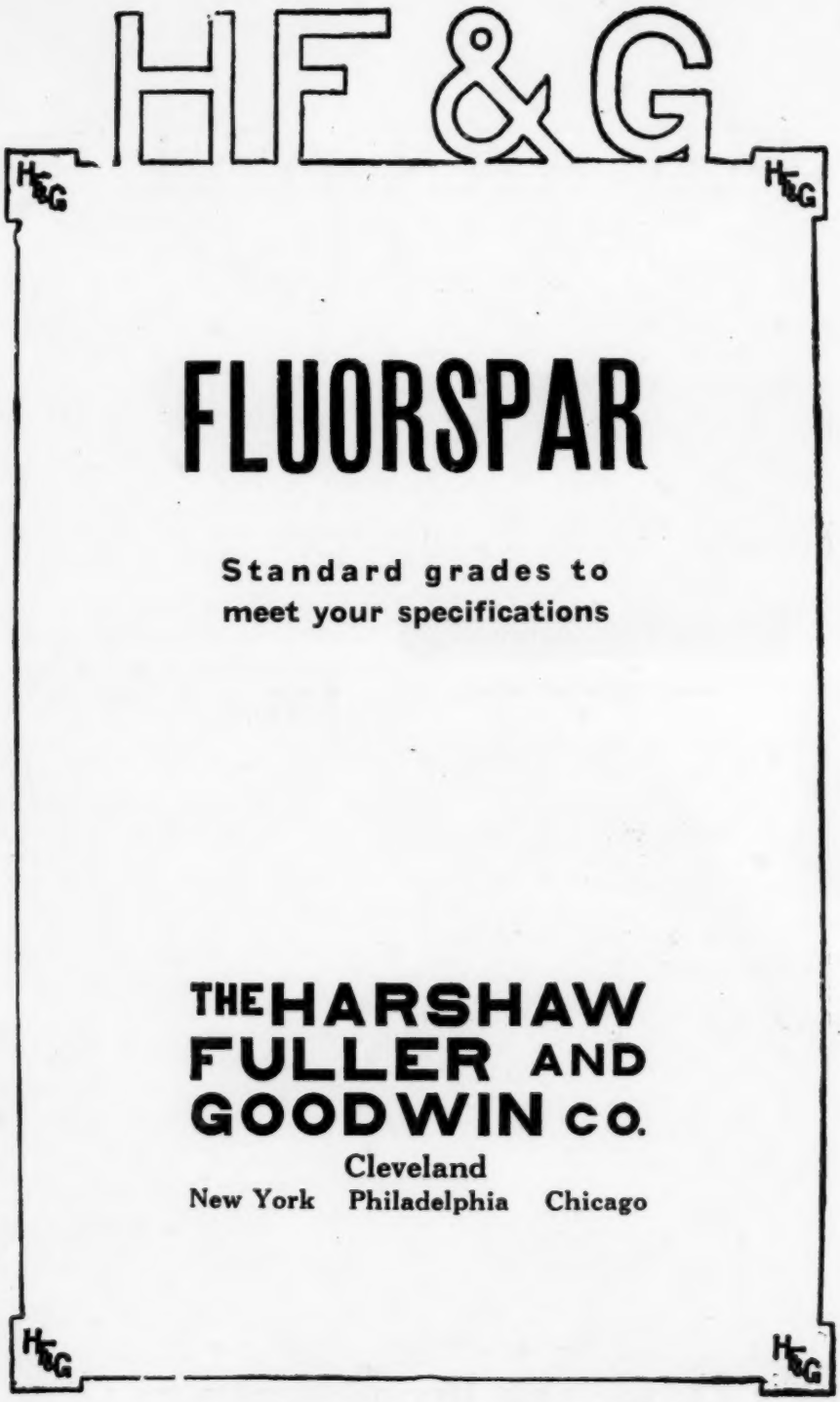

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JOURNAL
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A monthly journal devoted to the arts and sciences related to the silicate industries.

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Vol. 4 **December, 1921** **No. 12**

EDITORIALS

GLASS DIVISION PREPARES RESEARCH MATERIALS

The research committee of the Glass Division of the Society has perfected a plan for providing glass of desired compositions and desired form for investigators in this field. The material will be supplied free of charge and no limitation as to the nature of the research will be imposed. The recipients of the material will be under no obligations except that of publication of the results of their investigations. The committee, however, requests that wherever possible the JOURNAL of the American Ceramic Society be given preference in reporting the results. Persons who are interested are requested to address their inquiries to one of the following members of the Committee of Research: E. C. Sullivan, Corning Glass Works, Corning, New York; E. W. Washburn, University of Illinois, Urbana, Illinois; R. B. Sosman, Geophysical Laboratory, Washington, D. C.

This action of the Glass Division sets an example, which, with appropriate modifications might be followed by every division of the Society. Knowledge of where materials for research may be secured is not as widespread as it should be, and research workers in all ceramic lines will welcome an agency to whom inquiries can be directed and whose coöperation can be relied upon in securing such materials.

THE ST. LOUIS MEETING

The Twenty-fourth Annual Meeting of the American Ceramic Society will be held in St. Louis, February 27 to March 2, 1922, with headquarters at the Hotel Statler. St. Louis is an important center for refractories and heavy clay products, for enameled ware, glass and terra cotta and an unusually interesting series of inspection trips is expected. The program of papers for the sessions of the Society and its Divisions is in charge of Mr. R. D. Landrum, Chairman of the Committee on Papers and Program, care of The Harshaw, Fuller and Goodwin Co., Cleveland, Ohio, and titles of papers should be sent to him at an early date. Owing to the numerous undertakings which have been launched during the last year the coming meeting will be one of the most important ever held by the Society and a large attendance is expected.

ORIGINAL PAPERS AND DISCUSSIONS

A COMPARATIVE STUDY OF AMERICAN AND GERMAN QUARTZITES AS RAW MATERIALS FOR THE SILICA BRICK INDUSTRY[1]

By K. Endell

ABSTRACT

Properties determined.—Chemical composition, cone fusion temperatures, micro-structure in the raw state and after successive firings, and velocity of inversion on successive firings.

Comparative burning behaviors.—After a single firing to 1435°C the German erratic block quartzites of the tertiary age show a much greater expansion than the American quartzites. Hessian quartzite resembles the American.

Advantages of the German quartzites.—The use of the German erratic block quartzites for the manufacturing of silica brick of the highest quality is the more economical, both in preparation and burning costs, as compared with the American quartzites.

Introduction

As compared with fire-clay products, the silica refractories are growing in importance. Following the American example, Germany is also extending its utilization of silica brick to furnaces (with the exception of the Martin's furnace) in which heretofore only fire-clay refractories have been employed. This is due to the greater high temperature strength and greater thermal conductivity of silica as compared with fire-clay. The use of silica brick in coke ovens and of silica sections in the manufacture of illuminating gas will be recalled in this connection.

During the war there appeared in American scientific publications, several notable investigations dealing with quartzites

[1] Received Aug. 22, 1921.

and silica brick, among which those of Kenneth Seaver, J. Spotts McDowell, A. V. Bleininger, Donald W. Ross and H. Insley and A. Klein may be mentioned.[1]

From these investigations it is evident that the American silica brick industry employs a variety of quartzite different from that used in Germany. The variety employed in America is a fine grained quartzite, chiefly from the silurian or devonian ages, which in thin sections displays a closely intergrown mass of quartz granules without any bonding cement. In Germany, on the other hand, for the best quality of silica brick an erratic block quartzite of the tertiary age is still preferred. A thin section of this rock shows a structure composed of quartz granules with corroded edges, imbedded in a bonding cement.

The author showed in 1913[2] that an intelligent selection of quartzites for silica brick manufacturing could be made on the basis of a microscopic examination of the material, together with a determination of its rate of expansion on repeated firings. The purpose of the present investigation is to compare the American and German quartzites from this point of view. Through the kindly coöperation of Mr. Spotts McDowell of the Harbison-Walker Refractories Company of Pittsburgh and of Dr. Heinrich Koppers of Essen, I secured samples of the characteristic American quartzites of Medina, Baraboo and Alabama, together with some silica brick manufactured from them.

Chemical Composition of the Quartzites

The three American quartzites were compared with a Hessian quartzite, and with two typical German erratic block quartzites, one from Westerwald and one from Saxony. The chemical compositions and the cone melting temperatures of these six types of quartzites are shown in table I.

It is evident from these data that, as regards chemical composition, there are no essential differences among the six varieties

[1] Seaver, K., *Trans. Am. Instit. Min. Eng.*, **53**, 125(1916); McDowell, J. S., *Bull.*, **119**; *Am. Instit. Min. Eng.*, Nov., **1916**; Bleininger, A. V. and Ross, D. W., *This J.*, **18**, 519–23(1916); Ross, D. W., Bureau of Standards, Wash., *Tech. Paper*, No. **124**; Insley, H. and A. Klein, *Ibid.*, No. **124**.

[2] Endell, K., "Über Silikaquartzite," *Stahl u Eisen*, 1913, Nos. **42** and **45**.

TABLE I—PERCENTAGE CHEMICAL COMPOSITIONS AND CONE MELTING TEMPERATURES OF THE QUARTZITES

	U. S. A.[1]			GERMANY		
	Medina	Baraboo	Alabama	Westerwald	Saxony	Hesse
SiO_2	97.8	97.15	97.7	97.8	97.5	98
Al_2O_3	0.9	1.0	0.96	1.8	1.5	1.8
Fe_2O_3	0.85	1.05	0.8	0.4	0.5	
CaO	0.1	0.1	0.05	0.1	0.3	0.2
MgO	0.15	0.25	0.3			
Alkalies	0.4	0.1	0.3	not determined		
Cone-melting Temp.	Cone 36 ≃ 1790°C			Cone 35 ≃ 1770°C		Cone 36 ≃ 1790°C

[1] Data from K. Seaver, *op. cit.*

of quartzite. Only slight differences appear in the refractory powers as measured with Seger cones, doubtless due partly to the unreliability of this method in the case of such a highly viscous liquid as fused silica.

Microstructure

Photomicrographs were taken of thin sections of each material. Four of these are reproduced in figure 1. Those for the Baraboo and the Alabama quartzites are not given because they differ only slightly from that of the Medina. These three quartzites are non-micaceous and exhibit sharp, angular quartz grains, which, in the absence of bonding material, are closely intertwined, in part with re-entrant angles. A similar structure is exhibited by the Hessian quartzite, while that of the erratic block quartzites has an entirely different appearance.

A discussion of the origin of the latter varieties may be found elsewhere.[1] It is supposed that the silicic acid gel formed during

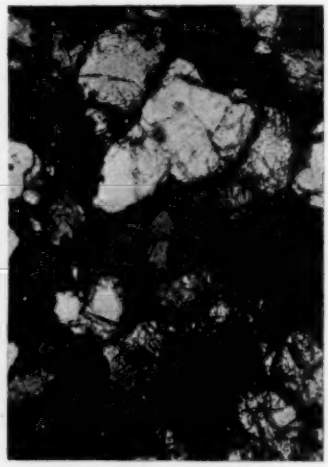
[1] Schubel, W., "Über Knollensteine u. verwandte tertiäre Verkieselungen," *Dissertation*, Halle, **1911**, p. 36.

Planck, A., "Petrographische Studien über tertiäre Sandsteine u. Quartzite," *Dissertation*, Giessen, **1910**, p. 43.

Endell, K., "Über die Enstehung tertiärer Quartzite im Westerwald," *Zentr. Mineralog.*, **1913**.

FIG. 1.—Photomicrographs of raw quartzite viewed under polarized light. Magnification ×110.

(*a*) Medina quartzite



(*b*) Hessian quartzite

Both quartzites display closely packed quartz grains without a binding cement.

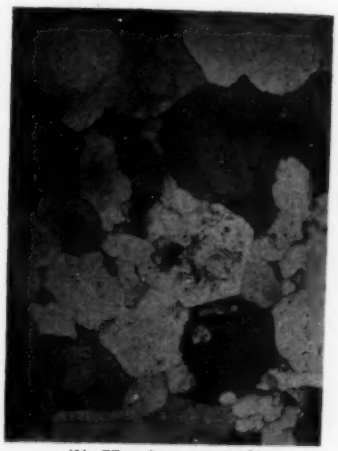
(*c*) Erratic block quartzite from Saxony

(*d*) Erratic block quartzite from Westerwald

Both quartzites display quartz grains with partially corroded edges which are embedded in a crypto-crystalline base of cement.

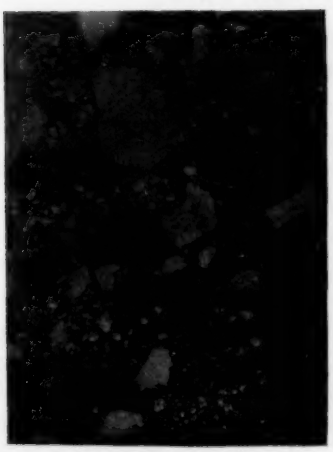
FIG. 2.—Photomicrographs of quartzites after a single firing to cone 15 (≈ 1435°C) in a porcelain kiln. Photographed under polarized light. Magnification × 110.

(*a*) Medina quartzite

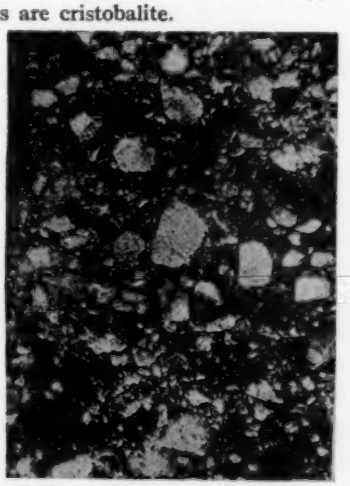


(*b*) Hessian quartzite

The greater part of the quartz crystals are still present. The black, apparently amorphous, spots are cristobalite.



(*c*) Erratic block quartzite from Saxony



(*d*) Erratic block quartzite from Westerwald

The greater part of the quartz crystals has been transformed. The cryptocrystalline ground mass has been completely converted into cristobalite and shows black in the photograph. No tridymite can be detected.

the tertiary age, either as such, or after admixture with fine sand, underwent, in the course of geologic ages, a recrystallization through the opal stage to chalcedony and quartz. In accord with this theory of the origin of the Westerwaldian and Saxon quartzites of the erratic block type, we find these materials displaying clearly rounded and in part strongly corroded quartz granules seated in a crypto-crystalline cement base. This basal cement is composed of crypto-crystalline silicic acid and shows black in the photograph,—that is, it behaves almost like an amorphous body.

Sample pieces (about .50 cm. thick) of the various quartzites were calcined to cone 15 (≈1435°C) in a porcelain kiln. Between cones 10(≈1300°C) and 14(≈1410°C) the firing was conducted at the rate of one cone per hour, while from cone 15 to cone 10, two hours were required. The kiln cooled from cone 15 to cone 10 in one hour, and thereafter, of course, still more slowly.

The photomicrographs (figure 2) taken from the calcined samples exhibited very marked differences which can be best discussed in connection with the curves of inversion velocity.

The Curves of Inversion Velocity of Quartzite on Repeated Calcinations to Cone 15 (≈1435°C) in a Porcelain Kiln

In the selection of quartzite for the manufacture of silica brick it is desirable that most of the inversion shall complete itself during the first firing, that is, that the brick shall acquire the specific gravity, 2.33, belonging to the form of silica stable at the high temperature, (*i. e.*, either tridymite or cristobalite according to the firing temperature). In order to determine these velocity curves, the specific gravity of the powdered material was determined in pycnometers of 3 cc. capacity. The results obtained are shown in figure 3.

It is evident from these results that under the given conditions, the transformation of both of the German erratic block quartzites, even after only one calcination, is more complete than that of the American or Hessian materials. The same result is also apparent from the photomicrographs shown in figure 2. On the second calcination, the American quartzites exhibit a much greater expansion and almost attain the limiting values which were

reached by the erratic block quartzites in the first calcination. The behavior of the Hessian material is, however, not quite so satisfactory.

Photomicrographs of thin sections of the quartzite after the second and third calcinations were also made. In no instance could tridymite be recognized with certainty. Its absence, however, is easily understood since, owing to the lack of fluxing materials, the conditions for the formation of the metastable cristobalite were much more favorable. The presence of cristobalite after several calcinations was also demonstrated by means of dilatometric cooling curves.[1]

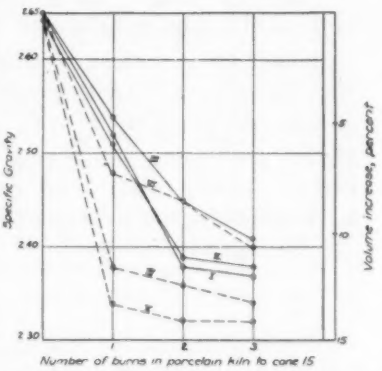


FIG. 3.—Curves of inversion velocity of the different quartzites on repeated burning in a porcelain kiln to cone 15 (= 1435°C). American quartzite, I, II, III; German quartzite, IV, V, VI.

Owing to the great uncertainties in working with quartzites no attempt was made to determine quantitatively the relative amounts of quartz, cristobalite and tridymite by the methods employed by the American investigators of silica brick.

Conclusions

1. The high temperature transformation of quartz into cristobalite takes place with the erratic block quartzites of Westerwald and Saxony much more rapidly than with the Medina, or Baraboo quartzites of America. The German quartzites of Hesse, however, resemble those of America.

2. Comparative studies of American and German silica brick have shown that the former, although composed of a quartzite which is less readily transformed than the German erratic block quartzites, frequently possess a lower specific gravity and consequently undergo a smaller subsequent expansion on heating to

[1] Cf. Endell, "Über Silikaquartzite," *Stahl u. Eisen*, l. c., figure 1.

1600°C, than do the German brick. It is therefore evidently entirely possible to manufacture first quality silica brick from both types of quartzites by proper attention to preparation of the raw materials and to the time and temperature of burning.

Since the rate of transformation increases with the surface exposed it is important in the case of the slower types of quartzites to follow the American practice of fine grinding and longer subsequent burning. In this way the same final result is attained as with the more rapid types of quartzite which are almost completely transformed in a single burn. The manufacture of the highest quality silica brick from the slower types of quartzite is, therefore, primarily a question of burning costs.

TECHNISCHE HOCHSCHULE
CHARLOTTENBURG, GERMANY

POROSITY: III. WATER AS AN ABSORPTION LIQUID

By Edward W. Washburn and Frank F. Footitt

ABSTRACT

Classes of absorption methods.—The ordinary immersion method has been shown by previous investigators to be unreliable. Simple immersion in low *vacuo* without boiling is also shown theoretically to be unreliable. An analysis of the results of previous investigators indicates the presence of unsuspected sources of error.

Effect of adsorbed gases upon dry weights of test pieces.—Dry air is shown to be without appreciable influence. Depending upon the humidity of the atmosphere, *adsorbed water vapor may cause errors up to 2 per cent* in the porosity value. Perfectly dry fired clay will remove water from conc. H_2SO_4 and from fused $CaCl_2$.

Saturation by boiling at atmospheric pressure.—A one hour's (and in one instance a 5 hours') boiling failed to saturate completely. On continued boiling the saturated weight increases linearly with the time and this in spite of the fact that appreciable quantities of dissolved materials are removed from the test piece by the hot water. This result is shown to be due to a gradual and continuous rehydration of the clay by the hot water. The error from this factor may amount to as much as 3% and the error from dissolved materials to as much as 2%, during a 3 hours' boiling. The nature of the dissolved material was determined.

Method of cooling the test piece.—It is recommended that the test piece be kept in a closed vessel over 95% sulphuric acid for several hours before its dry weight is taken.

Saturation procedure.—A vacuum method is described in which water may be employed as the saturation liquid under conditions where the above sources of error are reduced to a minimum. The method is *not* however recommended as *a primary standard.*

Necessity of a soaking period.—It is shown from theoretical considerations that *a soaking period is necessary* and methods are given for calculating and for measuring the minimum soaking period required for a given test piece and a given liquid of known penetrativity.

III. An Analysis of the Results and Conclusions of Previous Investigators

11. The Experiments of Beecher.—The only comparative studies of the different methods in use for measuring porosity by the absorption process which we have been able to find de-

scribed in the literature are those of M. F. Beecher[7] and of F. W. Walker, Jr.[8] In Beecher's investigation comparisons were made of the results obtained by the "immersion" method,[9] by the "boiling-in-air" method, by the "vacuum method," and by combinations of these methods.

Beecher's results with the immersion method show beyond question that this method can not be depended upon to effect *complete* saturation of a ceramic body even after long soaking. This confirms the results of other investigators[10] on this point, and demonstrates the inadequacy of this method for the purpose of securing accurate porosity data. This conclusion is moreover in entire harmony with the theory of the mechanism of saturation by immersion which has already been discussed.[11]

As regards the other two methods, Beecher reached the following conclusions:

> "Immersion in a vacuum showed slightly lower results on the average than the boiling treatment. From the data presented, it was decided that for ordinary laboratory work where the time element as well as accuracy is a factor, and where the results are for comparison only, within a given study, saturation by boiling for 45 minutes to one hour is sufficient for porosity and absorption determinations. Treatment with the vacuum alone does not offer better results."

From the data which he gives it is not clear that the vacuum which he employed was sufficient to boil the water. He states that the test pieces were "immersed and subjected to a vacuum of 29″ for three hours." Now under a vacuum of 29″ (*i. e.*, a pressure of 25 mm.) water will boil only if its temperature is maintained at 26°C, (about 78°F) and Beecher's paper contains no information concerning the temperature of the water in his experiments. If the water did not boil steadily, his experiments

[7] Beecher, *Trans. Am. Ceram. Soc.*, **18,** 73(1916).

[8] Walker, *Ibid.*, **18,** 446(1916).

[9] In the "immersion" method, a piece of the porous material is immersed in water for several hours and is then removed and weighed. On the assumption that all of the pores have been filled by water, the porosity is then calculable. In the so-called "boiling-in-air" method, the piece is boiled for a stated time in distilled water under atmospheric pressure. The procedure in the "boiling-in-vacuo" and "immersion-in-vacuo" methods is obvious.

[10] Ries, *Trans. Am. Ceram. Soc.*, **9,** 699(1907). Purdy and Moore, *Ibid.*, **9,** 693(1907). Walker, F. W., Jr., *op. cit.*

[11] See Part I, Sec. 6.

can scarcely be said to furnish a fair comparison of the two methods because the slow part of the absorption process is the last part, that is, the removal of the last traces of air from the pores of the body and this part of the process can obviously not be materially hastened by immersion under a vacuum insufficient to boil the liquid. A pump which maintains a vacuum of 29″ is quite good enough provided the water is kept warm enough to boil steadily. In the absence of any information concerning this point in the case of Beecher's experiments they can not, of course, be regarded as evidence of the superiority of the "boiling-in-air" method over that of "boiling-in-vacuo."

Furthermore, his conclusions that "where absolute accuracy is the important consideration, a combination of boiling, with the vacuum treatment, and a soaking period is the most effective means of saturation," will require modification in the light of some new information pointing to the existence of a hitherto apparently unsuspected source of error.

An analysis of his data as to the effect of a soaking period after boiling shows that, with the exception of one experiment[12] (which in the absence of any confirmatory experiments must be rejected because of its wide deviation from the others), the additional soaking period apparently produces on the average an increased absorption of only 0.18 ± 0.07 gram of water. Beecher states that his experimental procedure consisted in drying the test pieces with a soft towel and weighing them to a "tenth of a gram." With such a procedure, it might be doubted whether much significance should be attached to differences as small as 0.18 gram but for certain cases, theory indicates the necessity of a reasonable soaking period and this aspect of the subject will be more fully discussed below. (Sec. 29.)

12. Walker's Experiments.—Walker's experiments were in many respects similar to those of Beecher, although made upon biscuit wall tile, while Beecher employed grogged clay. Walker employed a vacuum of 28″ and evidently the water used was not warm enough to boil under this vacuum. It is thus clear that in neither of these investigations was the vacuum method given a really fair test.

[12] The 13th experiment recorded in his table II.

Walker, however, correctly suggests that the "boiling-in-vacuo" method, if properly carried out, *should* give the best results.[13]

In cases where it can not be carried out, Walker suggests a *five hours' boiling* at atmospheric pressure. As evidence that such a long period is necessary in order to insure complete removal of the air from the pores, he presents a graph which shows that the absorption of water increases *linearly* with the time. In view of the linear nature of this increase, there is evidently no assurance that the absorption is complete even at the end of five hours. As far as can be judged from the data presented, the absorption must continue to increase at the same rate, if the boiling is continued beyond five hours. On the evidence presented, therefore, it seems hardly justifiable to recommend the long boiling period of five hours.

It seemed to the writers that the results of Walker's experiments were rather to be interpreted as pointing to the existence of a hitherto unsuspected source of error in the "boiling-in-air" method, one which might prove so important *in certain classes of bodies* as to condemn the method entirely as a standard method for the determination of porosity values where a high degree of accuracy is sought. The present investigation had, therefore, as one of its first objects, the clearing up of the apparently anomalous behavior exhibited by the results of Walker's experiments.

IV. Preparation of the Test Pieces

13. Preparing and Shaping.—The body employed in the following tests was made from a common brick shale which was crushed with the aid of a jaw crusher and rollers, and then, without screening, was mixed with tap water until somewhat stiffer than a stiff mud brick. A 25-lb. batch was worked by hand on a marble slab, wedged into shape for the barrel of the briquette machine, and forced through the 1″ square die. The first trial was free from lamination and was wire-cut into four-inch

[13] But he implies that "expensive equipment" is essential. Such is, however, not the case. The method could have been successfully carried out with the equipment at his disposal, if water at a temperature of not less than 100°F had been employed. Judging from the boiling temperatures tabulated in Walker's paper, he was aware of this possibility, but for some reason, not obvious, he failed to make use of it.

pieces, fifty pieces being obtained from the batch. After air drying, the pieces were placed in a steam drier for 12 hours.

14. Firing.—An $8 \times 16 \times 2$ inch slab was placed in the bottom of the kiln, and this was covered with a second slab supported by two bricks, thus forming a chamber in which the briquettes were set in 2 ranks of 3 high and 2 files, making 6 piles with 6 briquettes in a pile, or 36 in all.

The kiln was closed in the usual manner and the burn started with wood, followed by soft coal. The water smoking continued for 2 hours, the temperature being raised 50° per hour for 4 hours and held for 2 hours at 200°. Oxidation was complete at 700°. The temperature was then raised about 30° per hour and 12 samples were drawn at 950°. These were placed in hot sand and allowed to cool slowly. Twelve more samples were similarly drawn at about 1050°. At 1150° the last 12 samples were drawn, the total time of burning being about 31 hours.

15. Selecting and Preparing the Briquettes for Test.—From the briquettes prepared and burned as just described, three of each class were selected, that is, 3 drawn at 950°, 3 at 1050°, and 3 at 1150°. These were selected so as to be as free as possible from cracks and other imperfections. If any superficial cracks or holes were discovered, they were enlarged with a knife so as to be sure that no pockets were hidden beneath them. No cracked briquettes were employed. The entire surfaces of the 950° and 1050° briquettes were made as smooth and as uniform as possible, and all corners and edges rounded by polishing with sandpaper. In the case of the 1150° briquettes, this smoothing was done with the aid of a file, since the briquettes were too hard to be affected by the sandpaper. The nine briquettes prepared in this way were then placed in the drying closet and heated at 120° for six hours. It was first desired to ascertain the effect of the nature of the atmosphere upon the "dry weight" of the test pieces. This was carried out as described below.

V. Effect of Adsorbed Gases upon the "Dry Weight" of the Test Piece

16. Adsorbed Water Vapor.—Four desiccators were prepared, the first one containing "1.86 sp. gr." H_2SO_4, the second

52 per cent H_2SO_4, the third 33 per cent H_2SO_4, and the fourth one pure water. The relative humidity of the air in these four desiccators was approximately 0 per cent, 33 per cent, 67 per cent and 100 per cent, respectively. The briquettes were removed from the drying chamber at 120°, placed in the first desiccator and allowed to cool over the concentrated sulphuric acid. They were then weighed as rapidly as possible in order to obtain their approximate dry weights, after which they were heated to a second time to 120° and allowed to cool once more over the sulphuric acid and again weighed.

After the dry weights had been obtained in this way, the briquettes were transferred successively to the second and to the third desiccators, their weights being determined after remaining in each desiccator for 24 hours. They were finally placed in the fourth desiccator over the pure water where they were allowed to remain for 120 hours, weighings being made every 24 hours. The results of this study are displayed in table I, the gains in weight in each instance being expressed in terms of per cent of the weight of the dry briquette.[14]

From these results it is evident that cooling in a dry atmosphere is essential to the most accurate results. Allowing the briquette to cool in the room or to stand for some time in the room may introduce errors in the "dry weight" up to as high as one per cent, depending upon the nature of the body, the humidity of the air at the time, and the period elapsing before the "dry weight" is taken.

17. Adsorbed Air.—In order to determine the amount of dry air which would be adsorbed by the body employed in the tests, three red-hot briquettes were transferred directly from the furnace to a previously heated hard glass tube. This tube was then evacuated to an X-ray vacuum and allowed to cool until its weight was constant to 0.1 mg. for 24 hours. Dry air was then admitted and the weight again determined as soon as pressure equalization had

[14] Cf. the results of Mellor and Holdcroft (*The Chemical Constitution of the Kaolinite Molecule.* Staffordshire "Collected Papers," **1**, 287. Griffin and Co., London, 1914) on the hydroscopicity of dry clay powder; and those of Day and Allen (*Am. J., Sci.*, **19**, 93(1905)) on powdered minerals, which show that orthoclase powder will adsorb, from the atmosphere of the room, moisture up to some 0.7 per cent of its weight.

TABLE I—ILLUSTRATING THE INFLUENCE OF ATMOSPHERIC HUMIDITY UPON "DRY WEIGHT" OF CLAY BODIES

Drawing temperature	Number of briquette	Weight after 24 hours in 0% saturated air	Percentage gain in weight on standing: 24 hours in 33% saturated air	24 hours in 67% saturated air	24 hours in 100% saturated air	48 hours in 100% saturated air	72 hours in 100% saturated air	96 hours in 100% saturated air	120 hours in 100% saturated air
	19	80.370	0.071	0.14	0.27	0.32	0.42	0.44	0.46
950°	18	81.528	.075	.14	.30	.39	.44	.46	.49
	17	76.147	.076	.14	.31	.40	.44	.48	.51
		Average	**0.074**	**0.14**	**0.30**	**0.37**	**0.43**	**0.46**	**0.49**
	29	84.061	0.080	0.17	0.57	0.87	0.97	1.08	1.12
1050°	31	82.698	.073	.17	.55	.85	.92	.97	1.00
	30	83.936	.057	.11	.34	.52	.55	.55	0.59
		Average	**0.070**	**0.15**	**0.49**	**0.75**	**0.81**	**0.87**	**0.90**
	22	83.149	0.008	0.02	0.02	0.05	0.05	0.06	0.07
	23	83.262	.007	.02	.03	.05	.06	.07	.07
1150°	30	84.517	.001	.004	.006	.009	.01	.01	.02
		Average	**0.005**	**0.015**	**0.019**	**0.036**	**0.04**	**0.05**	**0.05**

taken place. This process was repeated daily for 9 days. At first a slight inrush of air occurred each time the tube was opened to the atmosphere. This gradually diminished, and at the end of 9 days equilibrium had been reached and the weight no longer changed. The total increase in weight during this period was only 6 mg. in a total weight of 437 grams. The weight-in-air thus obtained was reduced to *vacuo*, and the calculated weight-in-vacuo thus obtained agreed with the observed weight-in-vacuo within the experimental error. In some additional experiments in which an attempt was made to estimate the amount of adsorbed air by releasing it into a vacuum positive results were obtained, but the amounts found were too small to affect appreciably the dry weight of a briquette.

It is thus evident that no significant error can arise from adsorbed air in the case of burned clay bodies.

We know, however, that many porous materials and powders are capable of taking up large quantitites of air and other gases.[15] This is true, for example, in the case of the colloidal silica developed by Patrick[16] for war purposes, also in the case of certain minerals such as the zeolites and chabazites which after dehydration were found by Friedel[17] to absorb 1.8 per cent of their own weight of dry air. It can not be said with certainty, therefore, that *all* ceramic bodies will not adsorb appreciable quantities of air, although this will probably be true of most of them after they have been fired above red heat. (Cf. Sec. 68 below.)

18. Adsorption of Water Vapor from "Dry" Air.—Although not capable of adsorbing significant quantities of air, burned clay bodies have a great avidity for moisture, as is evident from the experiments described in the Section 16. This was illustrated in a still more striking manner by the three briquettes employed in the above experiment. After removal from the hard glass tube, they were placed immediately in a desiccator and allowed to stand for 12 hours over $CaCl_2$. They were then weighed and found to

[15] For bibliography and review of this subject see Scheringa, K., *Pharm. Weekblad.*, **56**, 94(1919).

[16] Patrick, *J. Ind. Eng. Chem.*, **2**, 97(1919); *J. Am. Chem. Soc.*, **42**, 947 (1920).

[17] Friedel, Ch., *Compt. rend.*, **122**, 1006(1895).

have gained 9 centigrams or 0.04 per cent in weight. The following results were obtained when "1.86 sp. gr." sulphuric acid was used in place of $CaCl_2$ in the desiccator: Gain in weight for briquettes drawn at 950°, 0.02 to 0.04 per cent; 1050°, 0.08 to 0.11 per cent; 1150°, 0.05 to 0.06 per cent; 48 hours in desiccator.

It is evident from these results that a perfectly dry piece of burned clay is a more powerful drying agent than calcium chloride or sulphuric acid, since it will take water away from either of these materials.[18] The gain in weight under these conditions, while interesting as a phenomenon, is, of course, too small to have any practical significance in connection with porosity determinations.

VI. Comparison of the "Boiling-in-Vacuo" and the "Boiling-in-Air" Methods for Determining Porosity

19. Boiling-in-Vacuo.—The dry briquettes prepared as described above were placed in a filter bottle connected with a separatory funnel filled with distilled water. The air pump employed was a small rotary high vacuum pump driven by a motor. The filter bottle containing the briquettes was first evacuated until the pressure fell to less than a millimeter. The stop-cock of the separatory funnel was then opened and the water, which had been previously boiled under a vacuum, was admitted until the briquettes were covered. The vacuum pump was continued in operation and the briquettes *boiled* at room temperature in this way for one hour, after which they were removed, wiped with a *wet* cloth and weighed. The percentage increase in weight due to the absorption of water in this process is shown in column 5 of table II.

After weighing, the briquettes were transferred to a porcelain casserole, covered with water, and boiled in the open air for one hour, after which they were allowed to cool in the water and were

[18] The $CaCl_2$ used was taken from a bottle of the granulated material supplied for desiccator use. The sulphuric acid was the ordinary "C. P. 1.86" grade. Both products doubtless contained small amounts of water, and it was this water which was removed by the briquettes. Similar results to those given above are reported by Hillebrand, W. F. (*Geol. Survey Bull.*, **422**, 69(1916)), in the case of a powdered mineral which, after dehydrating at 280°, gained $1^1/_2$ per cent on standing in a desiccator over sulphuric acid.

TABLE II—COMPARISON OF THE "BOILING-IN-VACUO" AND THE "BOILING-IN-AIR" METHODS FOR DETERMINING THE POROSITY OF BURNED CLAY BODIES

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Drawing temperature	Number of briquette	Dry weight, grams	Weight after boiling 1 hour at 25°	Per cent gain in weight	Weight after boiling an additional hour at 100°C	Additional per cent gain	Weight after drying *in vacuo* at 100° followed by 1 hr's. boiling at 100°C	Per cent gain over original dry weight	Weight after two additional hours' boiling at 100°C	Additional per cent gain	Total per cent gain	Dry weight after removal of water *in vacuo* at 110°	Weight of material dissolved from clay body. Per cent	Net increase in dry weight of clay. Per cent.
	31*	82.440	102.022	23.8	102 .030	0.01	101.714	23.4	102.051	0.4	23.8	(81.500)		
950°	18	80.410	101.306	26.0	101.329	0.03	100.695	25.2	101.272	0.7	25.9	81.757		
	34	79.438	100.051	26.0	100.095	0.06	98.603	24.1	99.906	1.7	25.8	79.465		
Total		**242.29**	**303.38**	**25.2**	**303.45**	**0.03**	**301.01**	**24.2**	**303.23**	**0.9**	**25.1**	**242.72**	**0.43**	**1.3**
	5	83.914	102.730	22.4	102.763	0.04	102.211	21.8	102.801	0.7	22.5	84.187		
	29	81.433	99.985	22.8	100.044	0.07	99.683	22.4	100.010	0.4	22.8	81.699		
1050°	15	82.260	99.957	21.6	100.030	0.10	99.571	21.1	100.056	0.5	21.6	82.532		
	28	81.534	100.075	22.8	100.167	0.11	99.549	22.1	100.157	0.8	22.9	81.705		
Total		**329.14**	**402.75**	**22.4**	**403.00**	**0.08**	**401.01**	**21.9**	**403.02**	**0.6**	**22.3**	**330.12**	**0.17**	**0.47**
	39	84.330	89.876	6.59	89.957	0.09	89.318	5.91	89.849	0.6	6.5	84.443		
1150°	3	86.836	88.312	1.71	88.287	....	88.283	1.67	88.277	...	1.7	87.193		
Total		**171.17**	**178.29**	**4.15**	**178.24**	**0.03**	**177.60**	**3.76**	**178.12**	**0.3**	**4.1**	**171.64**	**0.083**	**0.36**

* Omitted in computing the value given in column 15. Probably low, owing to loss of small chip at some time during handling.

then removed, wiped with a wet cloth as before and weighed again. The additional increase in weight brought about by this process was practically nothing, as shown by the figures in column 7 of table II. In other words, the pores of the brick had apparently become completely filled with water during the vacuum treatment.

20. Boiling at 100°C.—It was next desired to study the rate of absorption of water by the briquette when boiled at 100°. For this purpose the briquettes used in the previous experiment were dried at 100° *in a vacuum* for one hour, after which they were transferred to a large porcelain casserole and boiled in water under atmospheric pressure for *one hour* and then, after cooling, were removed, wiped with a *wet* cloth and weighed. The per cent gain in weight due to the absorption of water in this process is shown in column 9 of table II. On comparing these figures with those of column 5, it will be noticed that they are uniformly lower. *In other words, one hour's boiling in the open air is not sufficient to completely fill the pores of the briquette with water.*[19] An additional two hours' boiling at 100° was then carried out, and the resulting additional gain in weight is given in column 11, the total gain resulting from the three hours' boiling being shown in column 12. On comparing the figures of column 12 with those of column 5, it will be seen that they are substantially identical. In other words, three hours' boiling in the open air was required in order to obtain the same weight of the water-filled body as was obtained after one hour's boiling in the vacuum.

All of the water in which the briquettes had been boiled was carefully collected, filtered, and evaporated to dryness. A considerable amount of dissolved material was obtained in this way, the weight of the material dried at 110° being shown in column 14 of table II. The briquettes were also dried again *in vacuo* at 100° for 4 hours and weighed. These second dry weights are shown in column 13 of the table. On comparing these

[19] A similar result has been found by Loomis, G. A. (*This J.* **1**, 393 (1918)), with fire-clay. The Report of the American Ceramic Society's Committee on Standards, Jan. 3, 1918, prescribed 45 minutes' boiling at atmospheric pressure for porosity determinations, but in a subsequent report issued in Feb., 1920, the time was increased to 2 hours.

second dry weights with the first dry weights, it will be seen that on the average they are decidedly larger, in spite of the fact that appreciable quantities of material were dissolved out of the briquettes during the water treatment. If we add to the second dry weights, the weights of the materials dissolved from the briquettes and subtract from the sum the original dry weights, we obtain the *net increase in weight of the clay* as a result of the foregoing treatment. This net increase expressed in per cent is shown in column 15.

21. Nature of the Dissolved Material.—In order to determine the approximate chemical composition of the material dissolved from the briquettes, three fresh briquettes of each class were boiled for four hours at 100° and the water was filtered, evaporated, and the residue partially analyzed. The results of these analyses for the 1050° class are shown in table III.

TABLE III—ANALYSIS OF THE WATER-SOLUBLE RESIDUES OBTAINED FROM THE BOILING EXPERIMENTS

Weight of residue dried at 110° = 0.29 gms.

Determination	Grams	Weight per cent
Ignition loss	0.0093	3.2
SiO_2	.0296	10.2
$Fe_2O_3 + Al_2O_3$	.0035	1.2
CaO	.0181	6.2
MgO	None	
Sulphates	None	
Alkalies (as chlorides)	0.2	

VII. Effect of Prolonged Immersion in Hot Water

22. Purpose of the Experiment.—The increase in the "dry weight" of the test piece shown by the data in table II apparently points towards a gradual and steady rehydration of the clay when it is boiled in water at 100°. If such a rehydration actually occurs, of the magnitude indicated, it would evidently explain the results obtained by Walker. In order to secure additional evidence on this rehydration hypothesis, two series of experiments were carried out.

23. Immersion at 100°.—In one of these a 1050° briquette was heated to redness, allowed to cool in a high vacuum, dry air

admitted, and the dry weight of the briquette determined without removing it from the vacuum tube. It was then allowed to stand in a desiccator, first over $CaCl_2$ and then over water, and the increase in weight observed. It was finally subjected to prolonged boiling at 100°, the dissolved matter collected and weighed, and the briquette finally dried for 3 hours *in vacuo* at 100°, weighed, ignited to red heat. and weighed again. The results are shown in table IV and in figure 2.

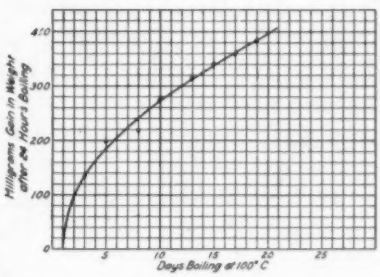


FIG. 2.—Rate of water absorption on prolonged immersion at 100°C.

TABLE IV—REHYDRATION OF BRIQUETTE NO. 32 (DRAWN AT 1050°)

Dry weight after heating to 1000° and cooling in high *vacuo* 81.625 gms.

Increase in weight (expressed in per cent of dry weight) produced by

Standing 12 hrs. over calcium chloride	0.04
Standing 72 hrs. over water	.47
Standing 96 hrs. over water	.53
Boiling 24 hrs. in water at 100°C	22.4
Boiling 72 hrs. in water at 100°C	22.6
Boiling 456 hrs. in water at 100°C	22.9
Loss of dissolved material	−0.36
The above treatment followed by drying *in vacuo* at 100° for 3 hours	.91
Plus material dissolved	1.27
The above treatment followed by two ignitions at red heat	0.2

24. Immersion at 200°.—For the experiments on the effect of prolonged immersion at 200°C, two briquettes were heated in an electric furnace to 1000°, allowed to cool in a desiccator over $CaCl_2$ and their dry weights determined. They were then placed in a porcelain dish and covered with distilled water. The dish was placed in an autoclave containing an excess of water, and this was heated to 200° and kept at that temperature for 15 hours.

After cooling, the autoclave was opened, the briquettes removed, the fragments collected in a filter, and the water evaporated to dryness to obtain the dissolved material. All the material thus obtained was dried at 120° and weighed. The increase in weight over the original dry weight amounted to 1.5 grams or 0.87 per cent.

25. Discussion of the Results.—As a result of these experiments it seems to be established beyond question that "burned" clay slowly rehydrates in contact with water, the extent of the rehydration naturally being dependent upon time, temperature, and the nature and condition of the body.

Since the experiments here described were completed, there has been published an account of an investigation by Laird and Geller[20] on the rehydration of clay. They found that clays calcined at low temperatures (600° to 800°), could be rehydrated by prolonged heating with water at 200–270°. This also agrees with results secured by Mellor and Holdcroft[21] with kaolinite dehydrated at 600°.

We may, therefore, conclude that the "boiling-in-air" method for determining the porosity of burned clay products does not fulfill the requirements of a "*standard reference method*" as outlined in the introduction.[22]

VIII. Interpretation of the Results and Their Bearing upon the Determination of Porosity

26. The Sources of Error, their Magnitudes and Significance.—The magnitudes of the various sources of error studied in this investigation may be conveniently summarized for comparison by tabulating them in terms of the percentage error which they produce upon the corresponding porosity values. For example, if the true porosity is 20 per cent and the value found by an inaccurate procedure is 20.2 per cent, the corresponding error in the porosity itself is evidently 1 per cent. The results of this

[20] Laird and Geller, *This J.*, **2**, 828(1919).

[21] Mellor and Holdcroft, *op. cit.*, p. 283.

[22] The American Society for Testing Materials in its "1921 Standards" prescribes five hours' boiling in the open air in determining the porosity of drain tile (p. 558) building brick (p. 578) and clay sewer pipe (p. 591). In the case of refractory materials, however (p. 623), a four hours' immersion in kerosene of known density at 25°C under a vacuum of 24 in. is prescribed. This degree of vacuum is not sufficient to boil the kerosene, and consequently will not materially shorten the time required for *completely* filling the pores. It might, however, cause some change in the density of the kerosene and possible consequent error, due to evaporation of the more volatile constituents. The error from this source is probably not significant for practical purposes, however.

method of representation are shown in table V and figure 3, positive values indicating that the error in question gives too large a value for the porosity, and negative values, the reverse.

In making any deductions from the results shown in table V the following considerations should be kept clearly in mind: (1) The values given are approximate only, but their order of magnitude may be taken as substantially correct. (2) They apply only to the particular body investigated, and must not be taken as representative of ceramic bodies in general. Other bodies may be expected to show either larger or smaller errors from the factors in question, depending upon the character of the body. With these facts in mind, we may proceed to a consideration of the significance of the data displayed in the table.

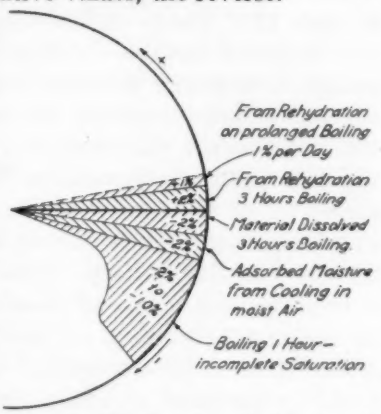

From Rehydration on prolonged Boiling 1% per Day
From Rehydration 3 Hours Boiling
Material Dissolved 3 Hours Boiling
Adsorbed Moisture from Cooling in moist Air
Boiling 1 Hour— incomplete Saturation

FIG. 3.—Typical magnitudes of various sources of error in the "boiling-in-air" method.

TABLE V—ILLUSTRATING THE PERCENTAGE ERROR IN A POROSITY DETERMINATION, PRODUCED BY EACH OF THE FACTORS INDICATED

Factor	Drawing temperature 950°	1050°	1150°
Cooling 12 hrs. over $CaCl_2$ or H_2SO_4	About —0.2 per cent		
Cooling 24 hrs. in 33% sat. air	—0.3	—0.3	—0.06
Cooling 24 hrs. in sat. air	—1.	—2.	—0.2
Boiling 1 hr. at 25°C	Taken as zero		
Boiling 1 hr. at 100°	—4.0	—2.2	—2 to —10
Boiling 3 hrs. at 100°:			
(*a*) From rehydration	+1.7	+0.76	+2.0
(*b*) From material dissolved	—1.7	—0.76	—2.0
Prolonged boiling at 100°:			
(*a*) From rehydration (See figure 3)	—	About +1 per cent per day after the 1st day	
(*b*) From material dissolved	Up to —2 per cent, probably all during the 1st two days		

27. Method of Cooling the Test Piece.—The most accurate method of obtaining the true dry weight of the test piece is, of course, to cool it in a perfect vacuum, as evident from the data in table IV. The error introduced by cooling in a desiccator over sulphuric acid or calcium chloride is, however, not large enough to have any significance as far as porosity measurements of most ceramic products are concerned. In fact, it may be doubted whether the adsorption of a small quantity of water vapor is really a source of error at all. The great avidity displayed by dry clay for water vapor shows that the first layer of water taken up from the surrounding atmosphere is very strongly held by the clay surface. This most strongly held adsorption layer is perhaps only one molecule deep[23] all over the exposed surface, and the water in this layer may have a density very much greater than unity, a density in fact corresponding to that which would be the result of a large increase of pressure.

Since it is probable that nearly all of such a compression would be borne by the first one or two layers of molecules next the surface, it is not unreasonable to suppose that the porosity results obtained would be fully as accurate, if this first surface layer could be adsorbed before the "dry weight" of the test piece is taken, and its weight, which would be small, neglected in comparison with the total weight of absorbed water. Since, however, there is no way of telling in advance *exactly* what condition of drying will give just this layer, neither more or less, the best that can be done in general is to prescribe some arbitrary but uniform method of cooling the test piece.

In order to obtain some information upon which to base the formulation of a suitable procedure for cooling the test piece preparatory to taking its dry weight, the following experiments were carried out:

A disk (15 cm. in diameter and 5 mm. thick) of a white ware body fired at cone 8 and having a porosity of about 60 per cent,

[23] Cf. Langmuir, *J. Am. Chem. Soc.*, **40**, 1361(1918) and **39**, 1848(1917); also McGavack and Patrick, *Ibid.*, **42**, 968(1920); Lamb and Coolidge, *Ibid.*, **42**, 1165(1920); and Washburn, "Introduction to the Principles of Physical Chemistry," 2nd Ed., 425–30. McGraw-Hill Book Co., N. Y., 1921.

was cleaned, weighed (133.422 gms.), heated to 1000°, transferred to a vacuum desiccator over 95 per cent H_2SO_4, allowed to cool 12 hours, and again weighed. Its "dry weight" obtained in this way was 132.860 ± 0.002 grams, and it gained very rapidly while in the balance case, although the latter had a dish of sulphuric acid in it. The dry piece was then placed over water, in order to saturate itself with water vapor, and weighed again. This time it *lost* weight very rapidly while in the balance case, its weight, as nearly as could be determined, being 133.450 grams.

The piece was finally returned to the vacuum desiccator containing the 95 per cent sulphuric acid and weighed at intervals to determine the rate of loss of adsorbed water.

In four hours its weight had fallen to 132.950 grams. Twenty hours later it had fallen to 132.930 grams, and an additional 48 hours' standing decreased it to 132.910 grams, after which it remained constant for 48 hours at 132.910 grams or 0.055 gram more than its original "dry weight." This 0.055 gram of adsorbed water is evidently held very firmly since it is not removed in 5 days by 95 per cent sulphuric acid.

The result of the above experiments suggests the following as a sufficiently exact procedure for securing the "dry weight" of the test piece for porosity determinations when water is used as the absorption liquid:

Place the test piece in a desiccator over 95 per cent sulphuric acid and allow it to remain there until it has reached "constant weight." If, as is ordinarily the case, the weighings are made to the nearest decigram, then it is evident from the above experiments that, for a very porous body, a few hours (2 or 3) in the desiccator is sufficient for the attainment of "constant weight." Previous to being placed in the desiccator, the test piece should be in contact with moist air for a short time in order that it may have an opportunity to adsorb its surface layer of water. If, after removal from the furnace, it is allowed to stand in the room until completely cold, this will ordinarily suffice to give it the requisite amount of adsorbed water. Evacuation of the desiccator will, of course, shorten the time required to attain constant weight.

28. The Vacuum Method of Porosity Measurement.—If the water absorption method is to be used at all as a permissible method for determining porosity where accurate results are desired, the vacuum method is obviously *the most trustworthy* procedure which can be employed. The most accurate method of carrying it out is obviously the following:

Place the test pieces, whose dry weights have been determined, in the vacuum vessel and evacuate the air until, on closing the connection to the pump, the manometer reading remains constant. Then close the connection to the pump and admit enough air-free, *cold*, distilled water to cover the test pieces. Disconnect the pump, and immediately break the vacuum. Allow the test pieces to soak until the water has completely penetrated the pores; then remove the test pieces, "dry" by wiping with a *very damp* towel or with some non-absorbent material,[24] and weigh. Evaporation during weighing may be prevented by inclosing the test piece in a weighing tube.

In order to carry out the method in the above manner, a good vacuum pump is necessary. The degree of vacuum required in any given case may be computed as follows: Let B be the barometric pressure, A be the fractional accuracy desired in the porosity value, and p be the pressure required in the vacuum vessel. Then from the laws of gases we find, for the extreme case of no channel pores,

$$p \gtrsim AB \qquad (1)$$

Thus if the accuracy required is 1 per cent of the porosity itself, then for p we find 7.6 mm. or 0.3 inch. With the above procedure, employing *cold* water and avoiding boiling or stirring, it is evident that both rehydration and solution would be reduced to a minimum, since the temperature is low and any dissolved material can escape from the test piece only by diffusion, which is a relatively slow process. The method could thus probably be safely employed even with under-burned bodies, if desired. Nothing is to be gained by employing hot water.

[24] Or better, by completely immersing the piece for a moment in mercury. This method was suggested by Prof. C. W. Parmelee. It has the advantage of automatically removing the surface water, as well as the water from those surface pores which are large enough to be penetrated by the mercury, thus eliminating the personal equation from the procedure.

If the pump available is not powerful enough to give the vacuum required for the above procedure, then the best method of operation is simply to *boil* the test piece *in vacuo* for the minimum period necessary[25] to effect complete saturation within the desired limit of accuracy. It is impossible to specify a length of time for this boiling process which will apply to every case.

29. Necessity for a Soaking Period.—In the above procedure no definite specification as to soaking period is given, nor is such an exact specification possible in general. Time is required for the water to penetrate the smallest pores of the body, and the smaller and more numerous these pores are, the greater will be the time required for complete saturation. The driving pressure behind the water is atmospheric pressure plus the surface tension pressure, and for very small pores is not sufficient to produce complete penetration except after very long periods of soaking.

The theory of the rate of penetration of porous bodies by liquids has been discussed by the senior author in another publication.[26] This theory shows that the amount of liquid which penetrates a porous body is proportional to the square root of the time of soaking and to the square root of the ratio, $\frac{\gamma}{\eta}$ of the surface tension of the liquid to its viscosity, for all cylindrical pores except those of molecular dimensions. Thus, if the pores of a briquette filled to the extent of 10 per cent in 2 minutes, it would require at least 3 hours and 20 minutes' soaking in order to fill them completely, assuming them to be of uniform dimensions.

The time required for complete penetration can be greatly reduced by the use of external pressures of several hundred atmospheres, as has been shown by Cude and Hullett,[27] and for very dense bodies with excessively fine pores, the use of such pressures offers the only hope of securing accurate porosity values by any absorption process. Equipment for producing such pressures is not ordinarily available in ceramic laboratories at the present time, however, and fortunately for many cases met with in actual

[25] To be found by trial. See Sec. 30*b* below.

[26] Washburn, "The Dynamics of Capillary Flow," *Phys. Rev.*, **17**, 280 (1921).

[27] Cude and Hullett, *J. Am. Chem. Soc.*, **42**, 400(1920).

practice, it is not important to include in the measured porosity these very small pores.[28]

Until further data are available, therefore, it would seem best to prescribe a somewhat arbitrary soaking period, which can be ascertained in the following manner:

30. Determination of the Minimum Soaking Period.—(*a*) *By Calculation.*—The time required for water to penetrate a distance, l, along a small cylindrical capillary is given by the expression[29]

$$t = \frac{l^2}{rz} \tag{2}$$

where r is the radius of the capillary and z $\left(= \frac{\gamma}{2\eta}\right)$ is the *coefficient of penetrance* or the *penetrativity* of the liquid. For water at room temperature

$$z = \frac{74}{0.02} = 3700 \text{ cm./sec.} \tag{3}$$

For l we may safely write $^1/_2\, l_{max}$, where l_{max} is the length of the longest straight line wholly within the test piece. The value of r would depend upon the character of the body and the accuracy demanded. Thus for common clay products we might write $r = 0.5 \times 10^{-4}$ cm., that is, we would be satisfied as soon as all pores, with diameters not less than 0.001 mm., were filled with the liquid. With these assumptions equation (2) becomes

$$t = \frac{4l^2_{max}}{3} \tag{4}$$

Thus for a briquette 4 in. long, we would have $l_{max} = 12$ cm. and hence, $t = 192$ sec. $= 3.2$ minutes.

With a material such as electrical porcelain for high tension insulators, it is necessary to take account of pores of much smaller diameter probably down to 10^{-5} mm. which is about a hundred

[28] Such materials as high tension electrical insulators, spark plug bodies, etc., of course, constitute exceptions to this statement, and the results of Cude and Hullett, referred to above, point to the desirability of employing a high pressure equipment for porosity studies on such bodies, or better the substitution of a gas in place of the liquid as the pore filling agent. This latter method will be described in the sixth paper of this series.

[29] Washburn, *op. cit.*, p. 280.

times molecular dimensions. Since the soaking time varies inversely as the pore diameter, the soaking time would be multiplied 100 fold, if pores as small as 10^{-5} mm. were included. Thus, for the briquette used in the above example, this would mean a soaking time of 5 hours, at least, thus emphasizing the necessity of employing high pressures when determining with accuracy the porosity of highly vitrified bodies by the absorption method.

(*b*) *By Direct Experiment.*—The calculated value obtained as described above is a minimum value only, because the calculation takes no account of the possible presence of pocket pores or pores whose diameters increase toward the interior of the body. Such pores would fill more slowly than the cylindrical pores. The actual soaking period required can be determined by suspending the immersed piece from the arm of a sensitive balance and noting the time required for it to attain its maximum weight. This maximum weight can, if desired, be determined in advance by the method which will be described in the sixth paper of this series.

31. Boiling at Atmospheric Pressures.—This method is evidently not sufficiently reliable for a standard reference method. In the cases studied, a one hour's boiling failed to produce complete saturation by from 2 to 10 per cent. Three hours' boiling gave the correct result, but only because the loss of weight due to dissolved material (1 to 2 per cent) just compensated for the gain in weight due to rehydration. Since there is no way of predicting in advance what period of boiling is necessary in order that these two errors shall just cancel each other, it is evident that the method should be rejected entirely as a *general standard*. There are, of course, many cases where it can be safely employed and will give results quite accurate enough for the purpose in hand. In any case where it is so employed, however, evidence that the errors are in fact negligible for the purpose in hand should be available. In this connection the following experience with the "boiling-in-air" method is worthy of mention. A standard size test piece of a stoneware body after firing to cone 10 was boiled in distilled water for 5 hours under atmospheric pressure. After removal and weighing it was found to have absorbed an amount of water corresponding to a porosity of 3 per cent. The actual porosity

of this same test piece was, however, later shown to be 15 per cent.

Part IV of this paper will deal with the use of petroleum products as absorption liquids.

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POROSITY IV: THE USE OF PETROLEUM PRODUCTS AS ABSORPTION LIQUIDS

By Edward W. Washburn and Elmer N. Bunting

ABSTRACT

Advantages of petroleum products.—Avoidance of: slaking, chemical reaction, adsorption, and solvent action; but longer soaking time is required.

Paraffine and vaseline.—Materials having high fluidity when hot, and comparatively low fluidity when cold, permit surface of saturated test piece to be brought to definite and reproducible condition with all surface pores full. Paraffine may be used but vaseline is preferable because it undergoes no change of phase on cooling.

Procedure and results.—A saturation procedure is described and comparative results given.

Density and penetrativity of vaseline.—Sp. gr. $\frac{23°}{4°}$ 0.8730, $\frac{32°}{4°}$ 0.8684, $\frac{42°}{4°}$ 0.8624. Penetrativity between 100° and 200°C $= 0.063\ (t - 30)^{\frac{1}{2}}$ cms./sec. A *penetratimeter* for determining the penetrativity of liquids is described.

IX. Introduction

32. Present Practice.—In order to avoid the slaking action which water has on clay in the raw state, it is customary to substitute kerosene in place of water in measuring the porosity of raw clay bodies. In order to saturate the body with the kerosene, a 12-hours' soaking is prescribed in the "Tentative Methods" of the American Ceramic Society.[31] The American Society for Testing Materials[32] recommends the use of kerosene in place of water for determining the porosity of refractory products, and prescribes a 4-hours' soaking in kerosene at 25°C under a vacuum of 24″.

So far as we have been able to discover, the above references practically cover the literature with regard to the use of petroleum products as absorption liquids. The remaining literature adds nothing of importance to the subject, and there seem to

[31] "Rep. of the Comm. on Stands.," p. 14, 1918.

[32] A. S. T. M., "1921 Book of Standards," p. 623.

be no conclusive data available from which the efficiency of the method can be judged.

33. Advantages and Disadvantages.—For use as the absorption liquid, the obvious advantages of a petroleum product, over water, are the following: (1) absence of slaking action on raw clay, (2) little, if any, solvent action on the constituents of the body, (3) no tendency to combine chemically with the constituents of the body, and (4) much less tendency to be adsorbed on the surface.

The disadvantages doubtless vary somewhat with the particular material employed, and require investigation before their nature and magnitude will be definitely known in each case. The following disadvantages and possible sources of error in the use of such a liquid as kerosene, however, seem to be obvious.

(1) There is no evidence that simple immersion at room temperature and at atmospheric pressure will effect complete saturation in any reasonable time. Judging from the behavior of water in this respect, a simple immersion process would certainly not be very accurate.

(2) The rate of penetration of kerosene into a clean pore is much less than that of water. The ratio $\frac{t_w}{t_k}$, of the immersion times required in order to give the same degree of penetration in the cases of water and of kerosene, respectively, would be (cf. Sec. 29 above) $\frac{t_w}{t_k} = \frac{z_k}{z_w}$ = about 0.05,[33] that is, the penetrativity of water is about 20 times that of kerosene at room temperatures.

(3) Boiling at atmospheric pressure would obviously require the use of a still provided with a return condenser, and a gradual change in density due to decomposition ("cracking") occurs under these conditions. Furthermore, the fire risk associated with such a procedure would be a decided disadvantage.

34. Purpose of the Investigation.—It seemed to the writers

[33] This value for the relative penetrativities of these two liquids was determined in this laboratory by G. E. Sladek, using a penetratimeter of our own design. (See Sec. 37 below.) The above conclusions hold only for clean pores, such as those of a fired body. In pores which were contaminated with any material of a greasy nature the behaviors of the two liquids in this respect might be reversed.

that all of the advantages obtained by using kerosene in place of water might perhaps be secured, without the concurrent disadvantages, by employing a petroleum product which possesses a considerable degree of stiffness at room temperatures but attains a high degree of fluidity at the temperature of boiling water. The use of such a product would have the additional important advantage, lacked by every fluid material, of making possible a perfect cleaning of the surface of the test piece without the danger of removing any of the absorption material from the pores. This latter advantage would be especially important, for example, in the case of bodies with large pores.

X. Paraffine

35. Paraffine as an Absorption Material.—An initial investigation of paraffine as an absorption material was carried out, the procedure being as follows:

A supply of air-free paraffine was prepared by boiling it *in vacuo* at about 100° for several hours, and then allowing it to solidify completely *in vacuo*. A quantity of this paraffine, sufficient to cover the test pieces when melted, was placed in the vacuum vessel together with the weighed test pieces. After evacuating, heat was applied until the liquid paraffine attained a temperature of about 200°. The vacuum was then broken, and after a soaking period,[34] the contents of the vessel were allowed to cool to room temperature. The test pieces were then cut out of the block of paraffine, cleaned and weighed. The "effective density" of the paraffine was then determined by repeating the above experiment with a glass-stoppered pycnometer bottle substituted in place of the test pieces.

The above procedure obviously assumes that the thermal expansion of the test pieces is the same as that of the glass composing the pycnometer bottle which is indeed approximately the case. The error arising from this assumption will probably not exceed about one per cent of the porosity for most ceramic products, and the paraffine method is thus sufficiently reliable for many purposes. For a "*standard reference method*," how-

[34] The relative penetrativity of paraffine, in terms of water at 22° is 0.092 at 65°, 0.39 at 185°, and 0.45 at 215°C.

ever, it is desirable that even this degree of uncertainty shall not be involved. It was, therefore, decided to experiment with a material which possessed a considerable fluidity even at room temperature, but which was stiff enough so that it would not flow appreciably under the influence of gravity. Vaseline seemed to possess the desired characteristics, and it was therefore chosen for investigation.

XI. Vaseline

36. Preparation of the Vaseline.—Two liters of filtered vaseline (Chesebrough) were placed in a four-liter flask and boiled *in vacuo* (temp. 100°) for several hours, in order to eliminate any dissolved air or volatile constituents which may have been present. It was then allowed to cool *in vacuo*.

37. The Penetrativity of Vaseline.—The penetratimeter employed is shown in figure 4. It was manufactured from a capillary tube 0.5 mm. in diameter and 100 cm. long, by coiling it as shown and sealing on a glass stop-cock. The instrument was first standardized with water and, after cleaning and drying, was mounted in a bath of liquid vaseline, as illustrated in the figure. It was immersed until the end A was about 5 mm. below the surface of the liquid, the end B being about the same distance above the surface. As soon as temperature equilibrium was attained the stop-cock was opened and the stopwatch started. When the meniscus in the capillary reached a mark on the end B, the watch was stopped. The penetrativity of the vaseline is then equal to that of water, multiplied by the ratio of the time of penetrance of water to that of vaseline.

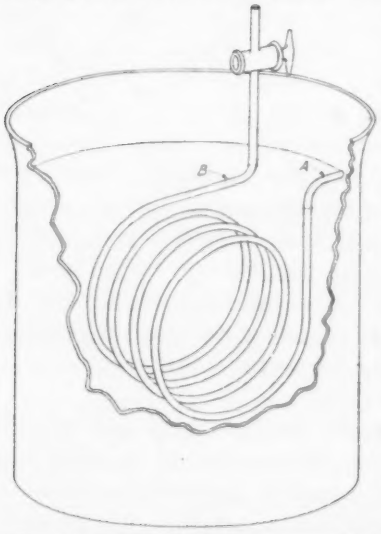

FIG. 4.—Penetratimeter for measuring the relative penetrativities of liquids.

The results between 100° and 200°C are expressed by the equation

$$z = 0.063(t - 30)^2 \text{ cms./sec.} \qquad (5)$$

38. The Specific Gravity of Vaseline.—The procedure was exactly the same as that described below (Sec. 47) except that a 50-cc. specific bottle was substituted for the test pieces. The specific gravity results are displayed in table VI and are expressed by the equation

$$d = 0.0203(46.8 - t) \qquad (6)$$

valid between 15° and 45°C.

TABLE VI—THE SPECIFIC GRAVITY OF THE VASELINE

Temperature C	23°	32°	42°
Specific gravity	0.8730	0.8684	0.8624

XII. Experimental Comparison of Water and Vaseline as Saturating Liquids

39. Preparation of the Test Pieces.—Two well-burned briquettes of a common brick clay and a piece of porous white ware tile were selected and, after cleaning and smoothing as described in section 43 below, were heated to 1000°C, cooled over 95 per cent H_2SO_4, and weighed in closed weighing tubes.

40. Saturation of the Test Pieces.—The test pieces were first saturated with water at room temperature by means of the preferred procedure described in section 47 below. They were then removed, wiped lightly with a damp cloth, and weighed in closed weighing tubes.

The saturated test pieces were dried slowly at 100° *in vacuo*, followed by a short ignition at 1000° and were then cooled as before and their "dry weights" taken a second time. They were then saturated with vaseline, using the procedure described in section 47 below.

41. The Results.—The pore volume of each test piece as determined by the two methods is shown in table VII. It is evident that the results obtained with vaseline are uniformly about 2.3 per cent higher than those obtained with water. If this difference is significant, and it probably is, the results obtained with the vaseline are clearly to be given the greater weight,

TABLE VII—COMPARISON OF WATER AND VASELINE AS SATURATION LIQUIDS

Material	Dry weight, grams		Pore volume in cc.		
	Original	After removal of water	With water	With vaseline	Diff. per cent
Briquette No. 1	83.987	83.988	8.22	8.40	2.2
Briquette No. 2	89.113	89.115	9.15	9.41	2.7
Porous tile	26.191	26.193	4.48	4.54	1.3

since, with the knowledge which we have of the chemical and physical properties of the class of hydrocarbons to which vaseline belongs, it is difficult to imagine any source of error which would cause vaseline to give results *higher* than the true values, while it is not difficult to understand how the results obtained with water should be low by the amounts indicated.

This, of course, does not mean that the results obtained with the vaseline are necessarily the correct values, since they also may be too low, owing to incomplete filling of all the pores. However, judging from certain other experiments with this type of body, it seems probable that the above results for vaseline are close to the correct porosity values of the test pieces used (cf. Sec. 68 below). With certain close textured stoneware bodies, however, it can be readily shown that neither water nor vaseline (nor any liquid, for that matter) will give correct porosity values except after weeks or months of soaking, and with such bodies the required soaking time is materially greater for vaseline than for water; that is, the results obtained with vaseline tend to be lower than those obtained with water. These experiments will be presented in detail in the sixth paper of this series.

42. Comparative Advantages of the Water and Vaseline Methods.—When carried out with cold water, the water absorption method will not be attended by any error due to rehydration. Furthermore, if the regular procedure recommended below is followed, the danger of loss of soluble materials is reduced to a minimum, owing to the short immersion period and as much avoidance of stirring, as possible.

The vaseline method, of course, possesses neither of these sources of error. Its other advantage over the water method is the definite and constant surface condition which can be attained and accurately reproduced when the pores are filled with a viscous grease. This is especially important in the case of a body (such as "Nonpareil" brick, for example) which has large surface pores which could not be kept evenly filled during weighing, if the absorption material were very fluid at room temperatures.

As a general rule, therefore, the vaseline method may be used to advantage whenever the accuracy desired is such as to require careful attention to the surface condition of the piece after removal from the absorption vessel or whenever errors due to the action of water on the body are to be feared. Owing to the long soaking time required the method is, however, not a satisfactory one to use with bodies having a considerable volume of very small pores.

To be continued

EARTHENWARE BODIES AND GLAZES[1]

By H. H. Sortwell

ABSTRACT

Effect of body composition on crazing.—Six bodies of each of 2 standard clay compositions were prepared with variable clay and flint content and after biscuiting at cone 8 were glazed with 21 earthenware glazes and glost fired at cones 4 and 6. The results indicated that the variability of the silica content of clays would not be great enough to produce crazing in a well-balanced glaze.

Effect of proportion and composition of frit.—A standard whiteware glaze was compounded in 6 different ways and several other glazes in 2 ways. It was found that the method of compounding had no effect on crazing but it affected the gloss and fusibility. Increase in the percentage of material fritted increased the gloss and fusibility. With the same percentage of frit the best glost and highest fusibility were obtained when the flint and part of the clay were included in the frit.

Effect of some variations in glaze composition.—Substitution of CaO by Na_2O, pound for pound, as well as direct addition of Na_2O increased crazing, improved gloss and increased the fusibility. Direct addition of feldspar increased crazing slightly and diminished gloss, but did not noticeably affect the fusibility. Substitution of $1^1/_2$ parts of feldspar for one part of flint to maintain the same fusibility increased crazing and diminished gloss. Direct addition of CaO improved gloss, increased fusibility and slightly reduced crazing.

Introduction

The occasional occurrence of crazing in the manufacture of white earthenware or semi-porcelain is the cause of the loss of many dollars annually. In nearly all plants crazing occurs intermittently and from causes which are difficult to detect. It was thought that occasional reduction in the silica content of the clays used might be one of the causes of crazing.

Since a variety of glazes was desired for this study, the effects of variation in the percentage and composition of the frit, and the effects of some variations in glaze composition were also investigated.

[1] Received April 2, 1921. Published by permission of the Director, U. S. Bureau of Standards.

Experimental

The bodies shown in table I were ground in ball mills six hours, filter-pressed, and wedged by hand for jiggering into discs $3^1/_2$ inches in diameter and $^1/_4$ inch thick. All of the bodies worked well in jiggering except 6 and 12, those of lowest clay content, which were a little short. The discs were burned to cone 8 in a small down-draft gas-fired kiln in 24 hours. The absorptions of the discs averaged from 4.3% to 6.3%.

TABLE I—BODIES

	1	2	3	4	5	6
English Ball Clay	18.5	17.2	16.0	14.8	13.5	12.3
Florida Kaolin	9.2	8.6	8.0	7.4	6.8	6.2
English China Clay	32.3	30.2	28.0	25.8	23.7	21.5
Maine Feldspar	14.0	14.0	14.0	14.0	14.0	14.0
Flint	26.0	30.0	34.0	38.0	42.0	46.0
	7	8	9	10	11	12
English Ball Clay	11.5	10.8	10.0	9.2	8.4	7.6
Tenn. Ball No. 5	8.1	7.5	7.0	6.5	5.9	5.4
Florida Kaolin	9.2	8.6	8.0	7.4	6.8	6.2
English China Clay	22.0	20.5	19.0	17.5	16.1	14.6
N. C. Kaolin	9.2	8.6	8.0	7.4	6.8	6.2
Maine Feldspar	14.0	14.0	14.0	14.0	14.0	14.0
Flint	26.0	30.0	34.0	38.0	42.0	46.0

With the exception of A, all of the frits were melted in crucibles and poured into water. Frit A was fired in a sagger in the bisque kiln to cone 8. The frits are shown in table II.

TABLE II—COMPOSITION OF FRITS

	A	B	C	D	E	F	G	H	K
Flint	24.0	6.30	....	24.0	18.0	...	...	...	...
Feldspar	...	..	15.6	...	...	21.00	13.30	18.10	21.00
Borax	4.38	4.38	4.38	4.38	4.38	4.38	18.50	18.50	18.50
Boric Ox	9.07	9.07	9.07	9.07	9.07	9.07	...	...	...
China Clay	2.33	2.33	...	...	...	...	...	...	...
Red Lead	...	..	...	17.40	8.80	5.73	...	...	3.38
Whiting	1.07	1.07	...	...	...	...	...	...	...
Soda Ash	...	..	...	...	...	...	...	3.76	...

TABLE III—BATCH WEIGHTS OF GLAZES

	A	B	C	D Frit used	E	F	G	H	K	Feld-spar	Flint	China clay	Whit-ing	White lead	Zinc oxide
1	34.0	..	..	..	..	..	..	..	..	34.0	..	3.6	15.0	19.7	3.5
2	..	16.3	..	..	..	..	..	..	..	34.0	17.7	3.6	15.0	19.7	3.5
3	..	..	23.0	..	..	..	..	..	..	18.4	24.0	5.9	16.1	19.7	3.5
4	..	..	..	48.4	..	..	..	..	..	34.0	..	5.9	16.1	..	3.5
5	..	..	..	..	34.0	..	..	..	..	34.0	6.0	5.9	16.1	9.75	3.5
6	..	..	..	..	..	34.0	..	..	..	13.0	24.0	5.9	16.1	13.25	3.5
7	..	..	..	..	..	..	23.0	..	..	20.7	24.0	5.9	12.0	19.7	3.5
8	..	..	..	..	..	..	..	30.0	..	15.9	24.0	5.9	8.0	19.7	3.5
9	..	..	..	..	..	..	..	30.0	..	15.9	24.0	5.9	..	19.7	3.5
10	..	..	..	..	..	..	23.0	..	..	20.7	24.0	5.9	..	19.7	3.5
11	..	..	23.0	..	..	..	..	..	..	18.4	24.0	5.9	..	19.7	3.5
12	..	..	..	..	34.0	..	..	..	..	34.0	6.0	5.9	..	9.75	3.5
13	..	..	..	..	..	..	..	30.0	..	29.4	15.0	5.9	..	19.7	3.5
14	..	..	..	..	..	..	23.0	..	..	41.4	10.0	5.9	..	19.7	3.5
15	..	..	32.0	..	..	..	..	..	..	51.4	..	5.9	..	19.7	3.5
16	..	..	..	..	..	34.0	..	..	..	46.0	..	5.9	..	13.25	3.5
17	..	..	..	..	..	34.0	..	..	..	46.0	..	5.9	16.1	13.25	3.5
18	..	..	..	..	..	34.0	..	..	..	51.0	..	5.9	..	13.25	3.5
19	..	..	..	..	..	..	23.0	..	..	25.7	24.0	5.9	12.0	19.7	3.5
20	..	..	..	..	..	..	23.0	..	..	48.4	10.0	5.9	..	19.7	3.5
21	.	..	..	..	..	..	..	..	34.0	40.7	10.0	5.9	..	15.9	3.5

The glazes (tables III and IV) were ground in ball mills, passed through a 150 mesh lawn, and applied to the discs fairly heavily by dipping. Two glost burns were made, cone 4 in 18 hours and cone 6 in 18 hours, the results of which are shown in tables V and VI.

BUREAU OF STANDARDS, WASHINGTON, D. C., APRIL 22, 1921
(Empirical Formulas)

TABLE IV—GLAZES

	K_2O	Na_2O	CaO	PbO	ZnO	Al_2O_3	B_2O_3	SiO_2
1	0.173	0.032	0.456	0.217	0.122	0.238	0.271	2.30
2–6	Same as one							
7	.175	.138	.344	.219	.124	.240	.276	2.32
8	.177	.243	.233	.222	.125	.243	.279	2.35
9	.230	.318	...	.289	.163	.317	.361	3.06
10	.266	.211	...	.334	.189	.366	.417	3.54
11	.317	.059	...	.399	.225	.437	.498	4.22
12	.317	.059	...	.399	.225	.437	.498	4.22
13	.295	.290	...	.265	.150	.375	.331	2.79
14	.368	.182	...	.288	.162	.452	.359	3.01
15	.478	.045	...	.305	.172	.570	.380	3.05
16	.478	.045	...	.305	.172	.570	.380	3.05
17	.292	.027	.390	.186	.105	.350	.232	1.87
18	.496	.044	...	.294	.166	.388	.367	3.16
19	.196	.135	.335	.214	.120	.263	.267	2.43
20	.398	.173	...	.274	.155	.483	.343	3.15
21	.398	.173	...	.274	.155	.483	.343	3.15

TABLE V—RESULTS OF CONE 4 GLOST BURN

1. Excellent commercial glaze. No crazing.
2. Underfired. Texture and gloss very poor. No crazing.
3. Underfired. Texture and gloss poor. No crazing.
4. Excellent glaze. No crazing.
5. Fair glaze. No crazing.
6. Fair glaze, but not as good as 5. No crazing.
7. Excellent glaze but crazed on bodies of 26, 30 and 34% flint.
8. Good gloss but crazed on all bodies.
9. Good gloss, but crazed on all bodies. Crazed more than 8 and gloss was not as good.
10. Poor gloss and crazed on bodies of 26, 30 and 34% flint. Crazed less than 9 and gloss was not as good. Crazed a little more than 7 and gloss was not as good.
11. Underfired. Poor gloss and texture but no crazing. Gloss was not as good as 10 nor 3.
12. Poor gloss but better than 11. No crazing.
13. Fair gloss but crazed badly on all bodies. Crazed more than 9 and gloss was not as good.

TABLE V (*Continued*)

14. Poor gloss and crazed on all bodies. Crazed more than 10 and gloss was not as good.
15. Poor gloss and crazed on all bodies of less than 46% flint. More crazing than 11 and gloss was not as good.
16. Fair gloss. Crazed on all bodies of less than 46% flint. Better gloss than 15.
17. Fair gloss. Crazed about the same as 15, but fusibility and gloss were improved.
18. Poor gloss and crazed on all bodies of less than 46% flint. More crazing and poorer gloss than 15.
19. Fair glaze but crazed on all bodies of less than 42% flint. Crazed more than 7 and gloss was not as good.
20. Poor gloss. Crazed on all bodies. Crazed more than 14 and gloss was not as good.
21. Fair gloss but crazed the same as 20.

TABLE VI—RESULTS OF CONE 6 BURN

1. Excellent commercial glaze. No crazing.
2. Very poor gloss. No crazing.
3. Poor gloss. No crazing.
4. Excellent commercial glaze. No crazing.
5. Good glaze. No crazing.
6. Fair glaze. No crazing.
7. Excellent glaze. Crazed on bodies of 26 and 30% flint.
8. Excellent glaze. Crazed on bodies of 26, 30 and 34% flint.
9. Good gloss. Crazed on all bodies of less than 38% flint.
10. Good glaze. Crazed on bodies of 26 and 30% flint.
11. Poor gloss. No crazing.
12. Fair gloss. No crazing.
13. Fair gloss. Crazed on all bodies of less than 42% flint.
14. Poor gloss. Crazed on all bodies of less than 42% flint.
15. Poor gloss. Crazed on bodies of 26 and 30% flint.
16. Fair gloss. Crazed on bodies of 26 and 30% flint.
17. Good gloss. Crazed on bodies of 26, 30 and 34% flint.
18. Poor gloss. Crazed on bodies of 26 and 30% flint.
19. Good glaze. Crazed on bodies of 26 and 30% flint.
20. Poor gloss. Crazed on all bodies of less than 42% flint.
21. Poor gloss. Crazing same as 20.

Effect of Variation in Body Composition on Crazing

The two original bodies used in this study were fairly typical of American factory practice, one being high in English china clay and English ball clay, and the other high in domestic clays, reducing the amount of imported clays used. The flint content

is 34% and the feldspar 14% in both bodies. From these two bodies, 3 and 9, two series were laid out maintaining the feldspar constant and replacing clay by flint through a range of from 26% to 46% flint, as shown in table I.

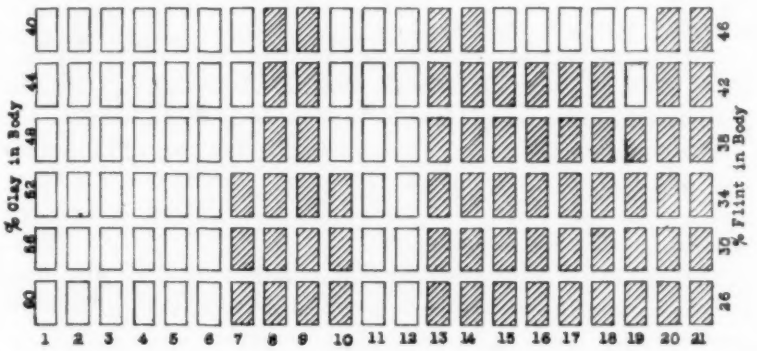

FIG. 1.—Earthenware bodies and glazes—Cone 4, cross-hatching denotes crazing.

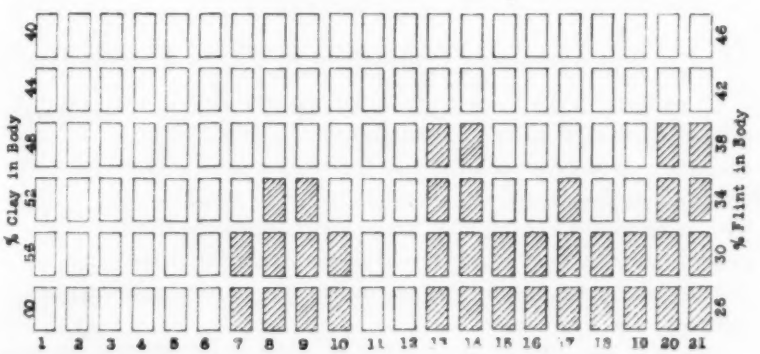

FIG. 2.—Earthenware bodies and glazes—Cone 6, cross-hatching denotes crazing.

From a study of figures 1 and 2, which show the extent of crazing of the 21 glazes on these bodies, the following points are noted.

The higher the percentage of flint in the body with a proportionate decrease in clay content, the fewer the number of glazes crazing on the body. The mesh of the crazing also decreased with increase

in flint. This agrees with the work of Seger,[1] Hecht,[2] Purdy,[3] and Ashley.[4] If the manufacturers of earthenware could overcome the mechanical difficulties in the forming of the ware, brought about by increasing the percentage of flint in the body at the expense of the clay, it is evident that the tendency for crazing to occur would be reduced.

The crazing decreased directly with the increase in flint content, there being no sharp difference noticed in the vicinity of 30% to 34% flint, in which range practically all of the bodies now in use lie.

There was no difference in the crazing in the two series due to the two different clay combinations used. Variation in the kinds and amounts of clays used does affect crazing but it was not studied in this investigation.

The difference in crazing due to variation in clay and flint content is so gradual that it is doubtful if reduction in the silica content of the clays from time to time would cause the occasional outbreaks of crazing occurring in most potteries. The standard glaze in all its variation in method of compounding did not craze even on the bodies of only 26% flint content.

Effect of Proportion and Composition of Frit in a Given Glaze

The standard whiteware glaze, laboratory No. 1, may be considered typical of those in common use in this country. The frit was made in saggers and fired in the bisque kiln. This glaze was compounded in six ways as shown in tables II and III. Since these frits, with the exception of A, were designed for use in the ordinary hearth frit kiln, they were chosen to maintain the proper fusibility instead of by pound for pound substitutions or substitution by chemical equivalents.

Frit A is the original frit used in factory practice. Frit B was obtained simply by reducing the amount of flint in the composition. In frit C, the whiting, china clay and flint were eliminated and sufficient feldspar used to render the frit insoluble. Frit D is the original frit without the whiting and china clay and with the

[1] "The Collected Writings of Herman A. Seger," pp. 575–576.

[2] Hecht, H., *Tonind.-Z.*, **1897**.

[3] Purdy, Ross C., *Trans. Am. Ceram. Soc.*, **7**, 79(1905) and **13**, 157(1911).

[4] Ashley, Harrison E., *Ibid.*, **13**, 259(1911).

addition of all the lead oxide in the glaze. This frit was made to determine the effect of a larger percentage of frit in the glaze. Frit E is also a flint bearing frit giving the same percentage of frit as that used in the original glaze. Frit F is a similar frit in which feldspar is used in place of the flint. The fusibility was kept uniform by using slightly more feldspar than flint and reducing the amount of lead oxide. The frits were all found to contain less than three per cent soluble material by the method employed by Blumenthal.[1]

Other examples of the same glaze compounded in two ways are glazes 11 and 12, 15 and 16, and 20 and 21.

The following summary may be made of the study of these results:

1. The way in which the glazes were compounded had no noticeable effect on crazing but had a great effect on fusibility and gloss.

2. Increase in the percentage of frit increased fusibility and improved gloss.

3. With the same percentage of frit, the most fusible glazes with the best gloss were obtained when the more refractory ingredients of the glaze (flint and part of the clay) were included in the frit. This left less thermal work to be done in the glost kiln.

4. In changing from a sagger frit to a frit-kiln frit, if the same glaze is to be used, the frit composition should be made more fusible by the addition of fluxes rather than by taking out part of the refractory ingredients.

Effect of Some Variations in Glaze Composition

Replacement of Calcium Oxide by Sodium Oxide.—Glaze 7 is the same as 3 with part of the CaO replaced by an equal weight of Na_2O. Glaze 8 is the same with a still further replacement of this kind. Substitution of CaO by Na_2O caused crazing, increased the gloss, and made the glazemorefusible.

Direct Addition of Sodium Oxide.—Glazes 11, 10, and 9 differ only in the Na_2O content and the variation in the frits necessary

[1] Blumenthal, George, *This J.*, **3**, 152(1920).

to introduce the required amounts of this ingredient. Addition of Na_2O improved the gloss, increased the fusibility and increased crazing.

Direct Addition of Feldspar.—Glaze 19 is the same as 7 with 5% feldspar added to it, and 20 is 14 plus 7% feldspar. These changes caused a slight increase in crazing and diminished the gloss but had no very noticeable effect on fusibility.

Substitution of Feldspar for Flint.—To maintain the same fusibility in substituting feldspar for flint, the substitution was not made on a pound for pound basis, but approximately one and one-half parts of feldspar were added in place of one part of flint left out. To glaze 9, 13.5 parts of feldspar were added in place of 9 parts flint to make glaze 13. To glaze 10, 20.7 parts of feldspar were added in place of 14 parts of flint to make glaze 14. To glaze 11, 33 parts of feldspar were added in place of all the flint, 24 parts, to make glaze 15. Replacement of flint by feldspar in this manner had no noticeable effect on fusibility but increased crazing and diminished gloss.

Direct Addition of Calcium Oxide.—In the glazes studied there were four cases showing the effect of the direct addition of CaO to a glaze. These are 3 and 11, 7 and 10, 8 and 9, and 16 and 17. The addition of CaO improved the gloss, increased the fusibility and reduced crazing slightly.

Effect of Raising Temperature of Glost Fire

Examination of Figs. 1 and 2 shows that raising the temperature of the glost kiln from cone 4 to cone 6 reduced the crazing in all cases where crazing had occurred at cone 4. This has long been recognized and is one method of reducing the tendency to craze; in fact, this change has been made in several plants recently for this purpose.

At cone 6 the gloss and maturity of the poorer glazes of cone 4 were improved. None of the glazes studied showed signs of overfiring at cone 6.

The author wishes to thank Mr. Homer F. Staley for advice and suggestions in the laying out and studying of the work.

BUREAU OF STANDARDS
WASHINGTON, D. C.
APRIL 22, 1921

CERAMIC ABSTRACTS

List of Principal Journals Abstracted

The following list contains the principal journals which publish material of ceramic interest. The information given has been obtained directly from the publishers and is correct as of July 1, 1921. Similar information concerning journals not here listed can be obtained from the list published annually in the last number of *Chemical Abstracts*.

Title and order. Black-face type used in the full titles given, designates that part of the title which is the official abbreviation of the periodical. The names of the periodicals are listed in the alphabetical order *of their abbreviations*.

Dates of appearance. The following symbols are used: *a.* (annual), *sa.* (semiannual), *sq.* (semiquarterly), *q.* (quarterly), *bm.* (bimonthly), *m.* (monthly), *sm.* (semimonthly), *bw.* (biweekly), *w.* (weekly), *sw.* (semiweekly), *irr.* (irregular).

Price. All prices given, unless mention is made to the contrary, are for subscriptions or single copies delivered in the United States. Prices in parentheses are for single copies; prices not so enclosed, unless otherwise stated, are for *one year's* subscription. F—franc, £—pound, s—shilling, d—penny, M—mark.

Publisher. Publisher's name and address, or the name and address of the person to whom orders may be sent, appear in italics.

Example. Full title of periodical, The American Journal of Science. Abbreviation, Am. J. Sci. Monthly. Price of a year's subscription, $6.00 in the United States. Price of a single copy, $0.50. Subscriptions may be sent to The American Journal of Science, c/o Edward S. Dana, New Haven, Conn.

American Journal of Science, The. *m.* $6 ($.50). *Edward S. Dana, New Haven, Conn.*

American Mineralogist, The. *m.* $3 ($.30). *Albert B. Peck, Mineralogical Lab., University of Mich., Ann Arbor, Mich.*

Berichte der Deutschen Keramischen Gesellschaft. *irr.* Price varies 5 to 10M. in Germany. *Des Verbandes keramischer Gewerke in Deutschland, Berlin-Wilmersdorf, Nikolsburger Platz 1, Germany.*

Brick and Clay Record. *bw.* $3 ($.25). *Industrial Publications, Inc., 610 Federal Street, Chicago, Ill.*

Brick and Pottery Trade Journal. *m.* 6s (6d) in England. *37 and 38 Shoe Lane, London, E. C.*

British Clayworker, The. *m.* 14s (1s) in England. *43 Essex St., Strand, London, W. C. 2.*

Bureau of Mines, Bulletins, Circulars and Technical Papers, *Government Printing Office, Washington, D. C.*

Bureau of Standards, Bulletins, Circulars and Technical Papers, etc. *Government Printing Office, Washington, D. C.*

Canadian Mining Institute Bulletins. *Sec'y's. Office, Rooms 3 and 4, Windsor Hotel, Montreal, Canada.*

Céramique, La. *m.* F35. *J. León Lefévre, 123 Rue de Rennes, Paris, France.*

Chemical & Metallurgical Engineering. *w.* $5 ($.25), $6 in special zones. *McGraw-Hill Co., Inc., 10th Ave., at 36th St., New York City.*

Chimie et industrie. *m.* F50 (F10). *Société de chimie industrielle, 49 Rue de Mathurins, Paris, France.*

Diamant. *Every 10 days.* $.75 a quarter. *Alexander Duncker, Leipzig, Keilstr. 1, Germany.*

Economic Geology. *sq.* $3 ($.50). *The Economic Geology Publishing Co., 41 N. Queen St., Lancaster, Pa.*

Engineering and Mining Journal. *w.* $5 ($.25). *McGraw-Hill Publishing Co., 10th Ave., at 36th St., New York City.*

Geological Survey Publications. *U. S. Geological Survey, Government Printing Office, Wash., D. C.*

Glashütte, Die. *w.* $4. *Dresden-A-24, Germany.*

Glassworker, The. *w.* $3 ($.10). *Commoner Publishing Co., Box 555, Pittsburgh, Pa.*

Glass Industry, The. *m.* $2 ($.20). *Glass Industry Publishing Co., Inc., 19 Liberty St., New York City.*

Glass-Industrie, Die. *w.* M20 for 3 months (M2). *Industrieverlag Spaeth & Linde, Berlin, C. 2., Königstrasse 52.*

Journal of the American Chemical Society. *m.* $7.50 ($.75). *American Chemical Society, 1709 G St., Wash., D. C.*

Journal of the Chemical Society. *m.* 4/4s (7s6d). *Gurney and Jackson, 33 Paternoster Row, London, E. C. 4.*

Journal of the Franklin Institute. *m.* $6 ($.60). *The Franklin Institute, Philadelphia, Pa.*

Journal of Geology. *bm.* $4 ($.75). *University of Chicago Press, 5750–58 Ellis Avenue, Chicago, Ill.*

Journal of Industrial and Engineering Chemistry. *m.* $7.50 ($.75). *American Chemical Society, 1709 G St., Wash., D. C.*

Journal of the Japanese Ceramic Society. $4. *Sec'y. Tojiro Kurahashi, 20 Omoteche 2-chome, Akasakaku, Tokyo, Japan.*

Journal of the Optical Society of America. *6 times a year.* $5 ($1). *John P. Smith Printing Company, Rochester, N. Y.*

Journal of the Royal Society of Arts. *w.* (1s.) *G. Bell & Sons, Ltd. York House, Portugal St., London, W. C. 2.*

Journal of the Society of Chemical Industry. *bm.* 4/4s (3s6d). *Society of Chemical Industry, Central House, Finsbury Square, London, E. C. 2, England.*

Journal of the Society of Glass Technology. *q.* $8 ($2.50). *Messrs. Richard Clay & Sons, Ltd., Blackfriars House, New Bridge St., London, E. C. 4.*

Keramische Rundschau. *w.* $5 ($.10). *Keramische Rundschau, G. m. b. H. Berlin, N. W. 21.*

Mineralogical Magazine and Journal of the Mineralogical Society. *q.* £1 (5s). *Simpkin, Marshall, Hamilton Kent & Co., Ltd., 31 & 32 Paternoster Row, London, E. C. 4.*

Mining Magazine, The. *m.* $4 ($.35). *Mining Publications, Ltd., 724 Salisbury House, London, E. C. 2.*

Mining and Metallurgy. *m.* $14 ($1.50). *American Institute of Mining and Metallurgical Engineers, Inc., 212 York St., York, Pa.*

Mining and Scientific Press. *w.* $4 ($.15). *Dewey Publishing Co., 420 Market St., San Francisco, Cal.*

National Glass Budget. *w.* $3 ($.10). *Geo. F. Eibel, 426 Fourth Ave., Pittsburgh, Pa.*

New Jersey Ceramist. *q.* $2 ($.75). *J. Herdingsfeld Co., New Brunswick, N. J.*

Pottery Gazette, The. *m.* 10s (1s6d). *Scott Greenwood & Son, 8 Broadway, Ludgate, London, E. C. 4.*

Revue de L'Ingenieur et Index Technique. *m.* F60 (F6). *Bureau d'Organisation Économique (B. O. E.), 124–126 Rue de Provence.*

Revue des Materiaux de Construction, 2e partie: Briques, Tuiles, Ceramique. *m.* F32 (F3). *F. Margry, 148 Blvd. Margerita, Paris, France.*

Schnurpfeil's Review. *m.* $10. *Ingénieur H Schnurpfeil, Reichenberg (Bohemia).*

Sprechsaal: Zeitschrift für die Keramischen, Glas-und verwandten Industrien. *w.* $5 ($.10). *Müller & Schmidt, Coburg, Oberer Bürlag 16.*

Tegel. *m.* $3 ($.50). *Sveriges Tegelindustrie Färoning Kungsgaton, 66 Stockholm, Sweden.*

Tonindustrie-zeitung. *tw.* $8 ($.10). *Chemisches Laboratorium für Tonindustrie, Prof. Dr. H. Seger & E. Cramer, Berlin, N. W. 21, Germany.*

Transactions of the Ceramic Society (England). 30s. *The Ceramic Society, Stoke-on-Trent, England.*

Transactions of the Iron and Steel Institute. (London), *28 Victoria St., London, S. W., England.*

Verre, La. *m.* F35 in Belgium. *10 Rue del' Industrie, Charleroi, Belgium.*

Zeitschrift für anorganische und allgemeine Chemie. About 3 vols. a yr., 4 nos. a vol. $4.40 ($1.20). *Leopold Voss, Leipszig, Dörrienstrasse 16, Germany.*

Zeitschrift für Technische Physik—Deutschen Gesellschaft für Technische Physik E. V. *m.* $8.00. *Johann Ambrosius Barth in Leipzig.*

Information Concerning the Obtaining of Patents

The following information is published by the courtesy of *Chemical Abstracts*. The data and directions given are correct as October 1, 1921. This information will be revised and published yearly in the December number of the Journal.

Copies of any Patent can be obtained for: United States, 10 cents, sent to the Patent Office, Washington, D. C.; Austrian, M. 5, 10 or 15, according to length, sent to Lehmann & Wentzel, 1 Kärnthnerstrasse 30, Vienna; Belgian, $2.00, sent to Office des Inventions, L. Duvinage, Brussels; British, 1s. (plus postage, usually ½ d., outside of the kingdom), sent by Postal or Postoffice Order, payable to the Comptroller-General, to the Patent Office, 25 Southampton Buildings, London, W. C. 2; Danish, Kr. 3 for each 5 pages, sent to the Patentkommissionen, B. Niels Brocksgade 14, Copenhagen; Dutch, Fl. 1, plus postage (Fl. 0.05), sent to Octrooiraad, Juliana van Stolberglaan, The Hague; French, 1 franc, sent to L'Imprimerie Nationale, 87 rue de Vielle de Temple, Paris; German, 15 M. sent to the Reichspatentamt, Berlin; Norwegian, Kr. 1 from No. 3,125 to No. 20,935 and Kr. 0.5 from No. 20,940 on, both plus postage, sent to the Library, Styret for the industrielle Retsvern, Drammensveien 4, Christiania; Swedish, Kr. 1.00 sent to Kungl. Patent & Registreringsverket, Stockholm; Swiss, Fr. 1.20 for each ten pages of copy, or in lots of ten or more Fr. 0.80, sent to the Bureau Fédéral de la Propriété Intellectuelle, Berne; Japanese, 5 Sen, plus postage, sent to "Hatsumei Kyokwai (Invention Association). 1, Yuraku Cho Itchome, Kojimachi Ku, Tokyo. Of Canadian patents, manuscript copies only are obtainable. They are furnished by Fetherstonhaugh & Smart, 50 Queen St., Ottawa, or by the Commissioner of Patents directly. Estimates of cost may be obtained in advance. In Italy descriptions and designs of inventions are not published but one can have copies made at the office of the Ministero per l'Industria, il Commercio ed il Lavoro, Rome.

In ordering a copy of a patent, the number of the patent, the date, the name of the patentee, and the subject of the invention should be stated.

General and Miscellaneous

1. Note on a method of determining the distribution of pore sizes in a porous material. EDWARD W. WASHBURN. *Proc. Nat. Acad. Sci.*, **7,** 115 (1921).—A granular sample of the thoroughly outgassed material is weighed and placed in a steel pressure bomb which is then evacuated until all adsorbed gases are removed. Pure mercury is then admitted to fill the bomb and a series of pressure and volume measurements are made at various pressures up to the highest pressure it is desired to employ.

The decrease in volume, ΔV accompanying a small pressure increase of Δp, in any part of the range must evidently be due to the filling of pores whose effective radii lie between the limits r and $r - \Delta r$, or

$$\frac{\Delta r}{\Delta p} = \frac{-2\gamma \cos\theta}{p^2}$$

where γ is the surface tension of the liquid and θ the angle of contact. From this relation the fraction of the total porosity due to pores having effective diameters between any two limits may be computed. E. W. W.

2. Diatomaceous earth. M. CHARPENTIER. *Rev. Mat. Constr. Trav. Pub.*, **141,** 109–111; **142,** 132–134; **143,** 150–152 (1921).—A general treatise on physical character, treatment, cost of working and industrial application. LOUIS NAVIAS

3. The recovery of lubricating oil. A. J. WILSON. *Petroleum World*, **18,** 29–30 (1921).—A résumé of the means commonly employed for treating lubricating oil which has already been passed through the engine and become too dirty to justify its further use without treatment. R. L. SIBLEY (*C. A.*)

PATENTS

4. Transporting fuller's earth, etc. L. G. HILT. Brit. 161,419, March 8, 1920. Fuller's earth, ground argillaceous rocks or marls, or other finely divided material or coarsely powdered or granular materials liable to produce dust are mixed with a soln. of Na_2SiO_3 or other binding agent soln. in H_2O and dried to form lumps that are dustless in transport. The powder, etc., is reformed by dissolving out the binder. (*C. A.*)

5. Coating materials; plastic compositions; coated fabrics; joint-making packing. J. A. LOCKE. Brit. 160,801, March 24, 1921. Coatings for Fe and smoke stacks consist of water-gas tar, menhaden oil, resinate of Mn, naptha or benzine with or without a drier, and the special pigment (without the linseed oil). An insulating paint consists of water-gas tar, menhaden oil, resinate of Mn, benzine, a drier, portland cement, asbestos, and soy-bean oil. A suitable drier consists of benzine, soy-bean oil and MnO_2. (*C. A.*)

6. Firing ceramic ware. ALLEGEMEINE ELEKTRIZITÄTS-GES. Brit. 150,814, March 29, 1921. In the firing of ceramic ware in tunnel ovens the heating of the high-temp. zone is interrupted at intervals to allow the goods therein to cool down to a temp. at which they are sufficiently hard to allow the trucks to be moved forward without risk of damage. The gas connections to two

adjacent tunnels may be so arranged that their high-temp. zones are fired alternately. During the interruption in firing the temp. of the preliminary heating zone of the oven is maintained or increased by auxiliary burners. Cooling devices may be fitted in the cooling zone and the heat abstracted may be used for drying. (*C. A.*)

Apparatus and Instruments

7. A simple optical pyrometer. H. LUX. *Elektrotechn. Z.*, **42,** 494–5 (1921); *Gas. u. Wasserfach,* **64,** 374–5.—The principle: the brightness of the filament of an incandescent lamp is adjusted by varying the resistance in the series, until it matches the brightness of the furnace, flame or other temp. source under investigation. Lux suggests a simplification of the standard Lummer-Kurlbaum pyrometer, thereby reducing the first cost appreciably. He uses an old camera and permits the image of the bright spot together with that of the filament to be focused on the ground glass of the camera. A milliammeter and a slide resistance complete the outfit. Full details are given. Operating range, 600° to 2100°. C. G. F. (*C. A.*)

8. The present state of pyrometry. H. WEISS. *J. phys. radium,* **2,** 33–52 (1921).—A general review. W. P. WHITE (*C. A.*)

9. Laboratory blue burner (Franke Model). HERMANN ZELLER. *Chem. Ztg.*, **45,** 386 (1921).—It is claimed that higher temps. than the ordinary Bunsen gives can be reached with half the gas consumption, and that with an equal gas consumption temp. of 1450–1850° can be reached. The top grid to prevent striking back is made of porcelain and can not burn out.
J. H. MOORE (*C. A.*)

10. British pyrometry practice. ERNEST J. DAVIS. *Foundry,* **49,** 463–7 (1921).—A review. E. H. (*C. A.*)

11. Thermoelements of non-precious metals for high temperature measurement. F. HOFFMAN AND A. SCHULZE. *Elektrotechn. Z.*, **41,** 427–33 (1920).—The usefulness at high temps. of a number of thermoelements made from wire or tubing was investigated. The Ni-Ni-alloy couples and the carbon-nickel-steel couples could be used at 1000–1200°C for 100 hrs. or more with only a little oxidation and without varying in E. M. F. more than equivalent to 10°C. The temp. is noted at which each couple can be used continuously without marked deterioration. Tables are given of the E. M. F. of the couples and the chem. compn. of most of them are included. Graphs of the E. M. F. of each element toward pure Pt and toward Cu are given. It was found that oxidation has very little effect upon E. M. F. of a couple as long as a continuous thread of the element remains. E. N. BUNTING

Chemistry, Physics and Geology

12. Silicon hydrides. IX. Reactions with alkali metal. ALFRED STOCK AND KARL SOMIESKI. Kaiser-Wilhelm-Inst. f. Chemie, Berlin-Dahlem., *Ber.*, **54B,** 524–31 (1921); cf. *C. A.*, **14,** 2305.

13. Kaolins, clays, bauxites, etc.; changes in volume under the action of heat. A. BIGOT. *Compt. rend.*, **172**, 854–7 (1921).—Test specimens were prepd. by grinding to 200-mesh, moistening with H_2O, and pressing into briquettes in steel molds. The specimens were heated to successively higher temps. 100° apart, their lengths being measured after cooling from each temp. The results are expressed by temp.-length curves, and from them it is concluded that bauxites, kaolins, etc. begin to shrink below 1000°, and only when they contain free SiO_2 do they show expansion below this temp. Clays and kaolins expand before reaching their fusion temps. but bauxites do not. Mixts. of kaolin and SiO_2 show very marked swelling before fusion. This property is utilized in prepg. *artificial pumice stone* by rapidly heating schist and porcelain to their swelling temps. J. S. LAIRD (*C. A.*)

14. The flocculation of soils. N. M. COMBER. *J. Agr. Sci.*, **10**, 425–36 (1920).—This is an attempt to correlate the flocculation of soil particles with the established facts of colloid chemistry. Account is taken of the two following important causes of complication bearing upon the action of electrolytes on the soil. First "the soil particles are 'protected' by org. and inorg. colloids; second, the soil is a system of particles of all sizes." Hence a comparison of flocculation in the soil with coagulation in a simple suspensoid soil is impossible. Further light upon this subject was expected from a study of the effect of alkalinity on flocculation. Very minute details of the expts. on 8 soils are given. A lengthy discussion of the results and the following summary conclude the articles: " 'Silt' like most insol. substances, when suspended in H_2O is most easily flocculated by Ca salts when the suspension is neutral. The addition of alkali stabilizes the suspension and renders flocculation more difficult. Soil 'clay,' however, behaves in an opposite manner; it pptd. from alk. suspensions more readily than from neutral suspensions. In this behavior clay resembles silicic acid and some other members of the so-called 'emulsoid' colloids. It is suggested that the clay particles are protected by such colloids and thus behave as an 'emulsoid' and not as a 'suspensoid.' If this is true, then the action of CaO, which being alkaline nevertheless flocculates clay, is seen to be in accordance with the facts of colloid chemistry. The view is advanced, and some experimental support of it is described, that clay, as an 'emulsoid,' protects the larger particles which by themselves are 'suspensoid.' The soil aggregates are conceived as having large nuclei surrounded by particles which become smaller from the center of the aggregate outwards, the clay ultimately imposing its 'emulsoid' nature on the whole aggregate, and on the whole soil in normal cases. Fine silt soils are not flocculated by $Ca(OH)_2$ on account of the inefficiency of the relatively small amt. of 'emulsoid' clay to protect the large 'suspensoid' surface exposed by the fine silt." R. B. DEEMER (*C. A.*)

15. Measurement of electrical conductivity in metals and alloys at high temperature. J. L. HAUGHTON. *Trans. Faraday Soc.*, June, 1920 (advance proof); cf. *C. A.*, **14**, 3060.—An app. for the measurement of elec. cond. at high temps., up to 1000°, is described. The principle on which the app. works

is the measurement of the voltage drop along a fixed length of the specimen, through which a constant current is passing. This voltage drop is proportional to the resistance between the points of contact so long as the current is kept const. (*C. A.*)

16. Measurement of high degrees of hardness. J. INNES. *J. Inst. Mech. Eng.*, **1920,** 915–32.—The hardness (H) of a material depends on the elastic properties, and the following formula is given as a means of detg. and measuring it:

$$H = (\pi^3/96).[(3 + 4N)^2(3 + N)]/N^3.(Q^3/C^2)$$

where N is the ratio of modulus of change of size to modulus of change of shape, C the modulus of change of shape, and Q the limiting shear stress. These three factors can readily be detd. separately, and if test pieces of moderate size (rods of 0.1 in. diam. and 3 in. long) are available, two of those constants, C and N, may be measured with almost any desired degree of accuracy. Q is more difficult to measure, especially with brittle materials. (*C. A.*)

17. Mechanical properties of plastic substances (steel, glass). Importance of reactivity. H. AND F. LECHATELIER. *Compt. rend.*, **171,** 695–9 (1920). From the results of torsion tests on glass as its temp. of annealing (540°,) and on mild steel at its temp. of forging (825°), it is shown that at a sufficiently high temp., and with small forces, plastic substances undergo successively three types of deformation: (1) An instantaneous elastic deformation which disappears immediately after the suppression of the force; (2) a subpermanent deformation, produced slowly and disappearing slowly after the suppression of the force, and having an order of magnitude comparable with that of the instantaneous deformation; (3) a viscous deformation continuing the subpermanent deformation; this is produced with a const. velocity and does not disappear after the suppression of the force. (*C. A.*)

18. Crystallization, solidification, and devitrification. A. PORTEVIN. *Rev. ing. index. tech.*, **28,** 165–77 (1921).—Review of general principles. A. P.-C. (*C. A.*)

19. The process of solidification as a problem of conduction of heat. H. C. BURGER. *Proc. Acad. Sci. Amsterdam*, **23,** 616–27 (1921).—The answer to this is given in a complicated mathematical form unsuitable for reproduction. E. D. WILLIAMSON (*C. A.*)

20. Observations of temperature during solidification. H. C. BURGER. *Proc. Acad. Sci. Amsterdam*, **23,** 691–704 (1921); *Verslagen Akad. Wetenschappen Amsterdam*, **29,** 288–301.—Salol was chosen as a convenient substance to expt. within an initial test of the theoretical results already obtained (see preceding abstract). A very fine thermo-element passed along a diameter of the cylindrical tube in which the exp. was performed and the galvanometer deflection was registered photographically as the material crystd. A max. temp. was reached when the solid-liquid boundary reached the thermoelement, but this max. was always below the m. p. of the solid. The temp. curve agreed well with theory. E. D. WILLIAMSON (*C. A.*)

21. The globular silica representing the siliceous clay south of the Paris basin. RANDOIN. *Compt. rend.*, **172**, 1046–9 (1921).—A petrographic study. L. W. RIGGS (*C. A.*)

22. Correlation of late glacial annual clay-bands in North America with the Swedish time scale. G. DE GEER. *Geol. För. Forh.*, **43**, 70–3 (1921).—G. has found that from 74% to 89% of the clay-bands seen in the U. S. agree with those in Sweden, extending from 720 to 1520 years before the end of the ice age. W. SEGERBLOM (*C. A.*)

23. The mineralography of the feldspars. I. HAROLD ALLING. *J. Geology*, **29**, 193–294 (1921).—An application of the phase rule and thermo-equil. diagrams to the feldspars. The feldspars belong to a 5-component system, but for most purposes it is necessary only to consider the K, Na and Ca. The plagioclase and the hyalophane series constitute a series of solid solns. while the K-Na and K-Ca series possess only limited soly. and constitute eutectiferous systems. It is believed that both the K and Na feldspars are dimorphous, each existing in 2 isomeric forms, depending upon the temp. and viscosity of the magma. Some feldspars contain nephelite in solid soln. but this mineral can not be regarded as isomorphous with the normal feldspars. Some adularias and microclines show microclinic twinning in thin sections but not in thin plates, which suggests that the operation of grinding possibly caused the inversion of the metastable Na orthoclase to Na microcline. Many-zoned plagioclase feldspars are to be explained by the process of normal crystn. under rapid chill instead of magmatic corrosion, while others are the result of complex processes in which the phenomenon of undercooling plays an important rôle. The application of the physical-chem. principles to the feldspar system may also furnish a means of solving such practical geological problems as the location of a fault or the origin of amphibolites. W. F. HUNT (C. *A.*)

PATENTS

24. Alumina, etc. H. G. WILDMAN. Brit. 161,310, Jan. 14, 1920. Clay is boiled with an alk. soln. preferably prepd. by treating a soln. of soda ash with a quantity of CaO insufficient to convert all the carbonate to hydroxide, and the clear liquor, after settling, is drawn off. The treated clay is mixed with H_2O, and SO_2 is forced into the resulting suspension until no more is absorbed. The pptd. SiO_2 is filtered off, and the soln. run into a vacuum pan fitted with closed steam coils. On heating, the Al sulfite is pptd., and the SO_2 that is evolved at the same time is stored for further use. The Al sulfite is removed, washed and ignited to Al_2O_3. The SO_2 evolved is recovered. If a trace of S remains after the ignition it may be washed out with dil. NaOH. The Na_2SO_3 soln. remaining after the Al sulfite is filtered off, if treated with CaO, yields NaOH soln. ready for treating fresh clay, and the pptd. $CaSO_3$ on ignition regenerates SO_2. When Fe is present, the clay is heated before it is treated with alkali so that it does not go into soln. with the Al. Cf. *C. A.* **14**, 603. (*C. A.*)

BOOK

25. Factory Chemistry. HAWKES, WM. H. New York: Longmans, Green and Co. 59 pp. $1.00 net. For review see *Am. J. Sci.*, **2,** 53 (1921).

Refractories and Furnaces

26. Experimental separation of lime in dolomite. R. T. STULL. U. S. Bur. of Mines. *J. Frank. Inst.*, **190,** 739 (1920); cf. *This J.*, **4,** 558 (1921).

27. The fundamentals of heat losses in metallurgical furnaces. P. ROSIN. *Metal. u. Erz,* **18,** 37–45, 78–88, 99–104 (1921).—A detailed mathematical consideration of heat losses with tables of *heat conductivities of refractories.*
R. S. DEAN (*C. A.*)

28. Selection of Fuel for Industrial Heating. ANON. *Chem. Met. Eng.*, **25,** 116–118.

CHARACTERISTICS OF VARIOUS INDUSTRIAL GASES

	B.t.u. per cu. ft.	Vol. of air for combustion	**Max. temp., °F	**Max. temp. with 100% excess air	B.t.u. per cu. ft. of foregoing mixture
Acetylene	1470	12	4200	2600	59
Natural	960	9.8	3300	2100	47
Coal or city	600	5.7	3500	2200	48
Coke oven	550	5.3	3400	2200	48
Carbureted water	580	5.2	3600	2300	50
Oil producer	450	4.9	3300	2100	47 (42)†
*Fuel	380	3.4	3500	2300	49
Water	300	2.4	3600	2400	50 (52)†
Producer	130	1.8	2800	2000	41 (28)†
Blast furnace	100	1.3	2500	1900	41 (28)†

*Gasification by continuous process using hot coke for water gas.

**With cold gas and air.

† Calculated by abstractor from values given in columns 1 and 2. H. F. S.

29. Theoretical considerations on the subject of the composition of the gases of combustion and the gasification of coal. J. SEIGLE. *Rev. metal.*, **18,** 81–91 (1921).—Stoichiometric calcns. on the compn. of the gaseous products of combustion. The formula is developed, $^{100}/Aa + 0.5d + 1.5e + f = 100$, where $A = \%$ N_2 in the dry entering gas, $a = \%$ N_2 in the moist gaseous product, $d = \%$ CO in the moist gaseous produce, $e = \%$ H_2 in the moist gaseous product and $f = \%$ water vapor in the product. Examples are given showing the application of this formula to (1) complete combustion by dry gas, (2) gasification by air more or less charged with O_2 or CO_2, and water vapor. Similar calcns. are made for *blast furnaces and for elec. furnaces.*
E. H. DARBY (*C. A.*)

30. The use of pulverized coal under stationary boilers. ED. LIÉVENIE. *Age de fer.*, **37,** 833–6 (1921).—Notes on the machinery and equipment re-

quired, the early troubles encountered in its application, the advantages of the system, and the method of operation. A. P. C. (*C. A.*)

See also No. 15.

Glass

31. Dispersion in optical glasses. F. E. WRIGHT. *J. Optical Soc. Am.*, **4**, 148–59 (1920); *Science Abstracts*, **23A**, 500; cf. *C. A.*, **14**, 3135.—A somewhat more extended treatment of the same subject is contained in a paper by the same author published in *This J.*, **3**, 783 (1920).

32. Glass manufacture; enamels; glazes. A. A. KELLY and B. D. JONES. Brit. 160,495, Nov. 20, 1919. In the manuf. of glass, vitreous enamels, and glazes, Na pentaborate is substituted for borax or boric acid, and the necessary adjustment of the alkali content is made in any suitable manner. (*C. A.*)

GLASS

33. Adressbuch der Glasindustrie in Deutschland. Verlag von Müller und Schmidt. Coburg. M43.

See also No. 17.

Enamels

34. The use of enameled bombs in calorimetry. C. MATIGNON AND (MLLE.) G. MARCHAL. *Compt. rend.*, **172**, 921–22 (1921).—The HNO_3 produced in the explosion attacks the enamel and is neutralized by it. The loss of acid may lead to an error of $^1/_2\%$. It is rendered negligible by first treating the enamel for some hours with dil. acid. W. P. WHITE (*C. A.*)

Cement, Lime and Plaster

35. Analysis of portland cement. FABIO FERRARI. *Giorn. chim. ind. applicata*, **2**, 434–7 (1920).—F. applies the following methods to the analysis of portland cements in order to secure great rapidity of execution without sacrifice of exactness. Coarsely powder the clinker in a steel mortar of the Abich type, then grind in an agate mortar to pass through 3600 mesh per sq. cm. Dry the substance in the air, and weigh out 3 samples, (1) for detn. of H_2O, (2) for detn. of loss on calcination, silicic, Al_2O_3, CaO and MgO, (3) for detn. of insol. silicic residue, Fe_2O_3 and SO_3. *Moisture.*—Weigh 1 g. substance in a large Pt crucible, heat for 1 hr. at 120°, cool in a desiccator and weigh. *Loss on calcination.*—Use an elongated crucible of 60 cc. capacity. Heat 1 g. substance in an elec. furnace for 30 min. at not less than 950°. *Total SiO_2.*—Treat the residue from the above calcination with 4 g. HNO_3 (d. 1.52), drop by drop, allowing it to run down the walls of the crucible. Keep the crucible covered as much as possible with a watch glass. On addition of HNO_3 and until the whole residue is moistened, stir the substance about with a glass rod. Place the covered crucible containing the now gelatinous mass in an oven at 100° for 15 min. Stir the substance about from time to time with the rod. Then add 30 cc. boiling H_2O acidulated with HNO_3. Keep the mixt. at incipient boiling for 8–10 min., then filter. Wash the residue with boiling H_2O. Keep

until the washings are no longer acid, using as little H_2O as possible. Dry the residue over the pump, ignite for 30 min. in the elec. furnace, and weigh. *Al_2O_3 + Fe_2O_3.*—To filtrate from the above SiO_2 detn. add 10 cc. 10% NH_4NO_3 soln., heat to ebullition, and ppt. with slight excess of NH_4OH free of CO_2. Allow the ppt. to deposit, filter, wash twice with boiling H_2O. Dissolve the ppt. by dropping upon it warm dil. HNO_3, repeat the pptn. with the NH_4OH, filter and wash the ppt. completely with warm H_2O containing 1% NH_4NO_3, dry over the pump, ignite and weigh. *CaO.*—Take the combined filtrates from the pptn. of the mixed oxides above, concentrate to 150 cc., heat to ebullition, and ppt. with an excess of concd. boiling soln. of NH_4 oxalate. Keep at rest for 2 hrs. at about 80°. Filter, wash carefully with warm 1% NH_4OH oxalate soln., burn while moist and ignite with gradual increase of temp. for 30 min. over the blast. Weigh the residue as CaO. *MgO.*—To the filtrate from the CaO pptn. rendered acid by HNO_3, add Na_2HPO_4 in excess, bring to boiling and ppt. with 80–90 cc. 10% NH_4OH. Allow the ppt. to deposit. After the lapse of an hr., filter through a crucible of the Gooch-Neubauer type, wash with $2^1/_2$% NH_4OH, dry and calcine in the elec. furnace, and weigh as $Mg_2P_2O_7$. (In absence of such a crucible, collect the ppt. on a filter, wash completely with $2^1/_2$% NH_4OH, dry, transfer as much as possible of the ppt. to a weighed Pt crucible, burn the filter in a Pt spiral, transfer the ash to the same crucible. Heat at first with small flame until no more NH_3 is given off, increase the heat slowly, until the ppt. is white. Weigh.) *Insol. SiO_2* (Siliceous residue).—Ignite 2 g. of the substance for 15–20 min., transfer to a procelain dish, and treat as above for total SiO_2, but using 1.19 HCl in place of HNO_3. (The substitution of HCl for HNO_3 is to facilitate detn. of Fe_2O_3 in the filtrate as described below.) Transfer the washed residue to a porcelain dish by means of boiling 3% Na_2CO_3 soln. Heat with 150 cc. of this soln. at near 100° for 20 min. Filter, wash the residue thoroughly, first with Na_2CO_3 soln., then H_2O. *Fe_2O_3.*—Take half of the HCl filtrate from the above detn. of insol. SiO_2. Add 10 cc. concd. HCl, bring to 200 cc., oxidize the Fe completely with Cl water. Cool, agitate, and add drop by drop, a cold clear 6% soln. of NH_4 nitrosophenylhydroxylamine. (*A*) (Prepn. of *A:* Place 1 l. H_2O in a large vessel, add 60 g. $PhNO_2$ and 30 g. NH_4Cl. Agitate to form an emulsion, and then while still agitating, add slowly, 1 g. at a time, 70–75 g. pure Zn in fine powder. Keep the temp. between 16–18° by addition of small pieces of ice. Reduction is complete when the odor of the $PhNO_2$ disappears. Filter on the pump, wash the $Zn(OH)_2$ with a little H_2O. Cool the filtrate to satn., when an abundant ppt. of PhNHOH forms. Dry this over the pump then for an hr. between filter paper. Dissolve in 400–500 cc. Et_2O, filter through dry folder filter. Cool the clear soln. to 0°, pass dry NH_3 through it for 10 min., then an excess (about 1 vol.) of fresh amyl nitrate. *A* forms at once as shining, snow-white crystals. Dry, wash with Et_2O, crush between filter paper, and preserve in a hermetically closed bottle in presence of $(NH_4)_2CO_3$. The product is easily sol. in H_2O, the aq. soln. remaining unaltered for weeks. The soln. should always be filtered before

using.) The characteristic brick-red ferric salt forms at once as ppt., pulverulent at first then uniting into easily friable large cryst. masses. Continue agitation, adding at least $^1/_5$ excess of the reagent (0.0833 g. *A* are necessary for 0.01 g. Fe), when the base itself will ppt. as a voluminous white, soft, pulverulent microcryst. powder. Allow the whole to stand 15–20 min., break up the mass with a glass rod, filter and dry the ppt. over the pump with moderate aspiration. Wash twice with cold H_2O acidulated with HCl, then with H_2O alone until the washings are no longer acid. Wash repeatedly with NH_4OH, and again a few times with H_2O alone. Dry completely, bring to redness in a closed Pt crucible, then ignite in the air. Weigh as Fe_2O_3. *SO_3.*—Take the other half of the HCl filtrate from detn. of insol. SiO_2, bring to 250 cc., heat, and ppt. with NH_4OH and $(NH_4)_2CO_3$ in excess. Allow the ppt. to settle, filter and wash. Add a drop of methal orange to the filtrate, neutralize with HCl, then add 1 cc. HCl (d. 1.17), and bring to boiling. While agitating, add 50 cc. boiling 2% $BaCl_2$ soln. Allow to stand 1 hr. at 90°, filter, wash, dry a little, ignite moist in Pt. crucible, weigh as $BaSO_4$. The above methods may be applied to the analysis of *limestones*, crude powders and *shales*. These should previously be weighed and then scorified at about 1400° (the shales first mixed with a known wt. of very pure $CaCO_3$) for 30–40 min. Weigh again, powder in an agate mortar, heat, and keep in desiccator, and make the analysis on an aliquot part. ROBERT S. POSMONTIER (*C. A.*)

36. Chemical analyses of cement as indicators of behavior. R. J. COLONY. *Eng. News-Record*, **86,** 736 (1921).—A résumé of a paper read before the Am. Inst. of Mining and Met. Engineers. C. recommends that the results of chem. analyses of cement be calcd. to show actual components of the cements and that the values thus obtained be used as a basis for judging the quality. C. also recommends a limiting value for the ratio between the CaO, and the sum of the SiO_2, Al_2O_3, and Fe_2O_3. J. C. WITT (*C. A.*)

37. Lime and cement industries in Algeria and Morocco. E. DARGERY. *Rev. Mat. Constr. Trav. Pub.*, **144,** 170–71 (1921).—A plea for the consolidation of the lime and cement industries in Algeria and Morocco for their own betterment and for the eliminating of foreign capital. Some import and export figures are given for 1919 and 1920. LOUIS NAVIAS

38. Law for hardening of cements. J. BIED AND E. GARNIER. *Rev. Mat. Constr. Trav. Pub.*, **144,** 168–170 (1921).—It has been found that the resistance to compression of a plastic mortar at 84 days can be calcd. from the compression data at 7 and 28 days. Over 800 tests for $^1/_3$ plastic mortar have borne this out. The equation is $R_{84} = K(2R_{28} - R_7)$, where R is resistance for the no. of days indicated, and K is a constant, being 1 for cements, and 1.25 for limes. This equation may be put in the form $\frac{y = at,}{t + b}$ being that of an equilateral hyperbola. For cements ($K = 1$) it may be reduced to $\frac{y = 5\,at}{28 + 5t}$ and for limes ($K = 1.25$), to $\frac{y = at}{t - 0.24}$, where t = time in weeks and y = corresponding resistance. The depth to which a sinker will fall in a

cement has been combined in an equation with the time. For cements $(t - 3.6)(h - 2.7) = 152$ and for limes $(t - 8.5)(h - 8.7) = 429$, where t = time in hours since the mixing of the mortar and h = depth in tenths mm. These equations have been tested, and express the exp. results. LOUIS NAVIAS

39. Slag brick. ANON. *Rev. Mat. Constr. Trav. Pub.*, **143,** 148–150 (1921).—Slag of composition SiO_2, 40.6%; CaO, 11.2%; Al_2O_3, 18.5%; Fe_2O_3, 22.8%; and MgO, MnO_2 and alkalies, 6.9%, is mixed with slaked lime, *e. g.:* 85–88% slag and 12–15% lime, and ground between stone mullers. Then 6–10% quicklime and 10–15% water are added, mixed and allowed to stand 12–36 hours. The brick are then pressed, steam dried, air dried and are ready for use. LOUIS NAVIAS

40. Lime industry in Egypt. A. DUPRAZ. *Rev. Mat. Constr. Trav. Pub.*, **143,** 145–146; **144,** 172 (1921).—Describes the pre-war method of calcining limestone in a primitive stone walled kiln, lined inside with crude brick, and using vegetable matter, *i. e.*, fibres, leaves, etc., for fuel. Describes the war method of utilizing unburned cinders and coals from railroads, furnaces, etc. LOUIS NAVIAS

41. What causes cement to be quick setting? BAILEY TREMPER. *Concrete* (Cement Mill Section), **18,** 144 (1921).—T. has observed that quick setting (or quick stiffening) cement is most likely to be produced when the temp. in the finishing mills is abnormally high. From expts. with gypsum and plaster of Paris, he believes that the effect is the result of dehydration of gypsum during the grinding process, when the temp. exceeds 110°.

J. C. WITT (*C. A.*)

42. Theory of the setting and hardening of Portland cement. FABIO FERRARI. *Giorn. chim. ind. applicata,* **2,** 620–4 (1920).—A consideration of the prevailing theories upon the action of Portland cement, supplemented by F.'s own expts., led to the following conclusions. The high temp. of consolidation of Portland cement, the normal presence in this of di-Ca silicate and of ternary silicates of the type $SiO_2 . Al_2O_3 . 2CaO$; $2SiO_2 . Fe_2O_3 . 2CaO$, in which all the Fe and nearly all the Al are comprized show that free CaO must be enumerated among the ordinary components of Portland cement. The CaO (normally in solid soln. and hence slowly attackable by H_2O) can be considered as an expansive agent only if present in excess or in such a form that it can produce on hydrating, tensions superior to the opposed reaction forces of the cementitious mass that contains it. On this basis, setting, properly speaking, must be looked upon as due to the adhesion of the $Ca(OH)_2$ with the hydraulically inactive elements and with the hydraulic elements not yet attacked by the H_2O during the lapsing period of time. (Free CaO gives rise to a hydrate with greater rapidity than does any other component of the Portland cement in the act of mixing, and during the short period, varying from a few min. to some hrs., that follows.) Hardening on the same basis, must be attributed to the development of contact mutually between hydrates and between the hydrates and the inactive components. This contact is due to the mobility which the active compds. acquire, in

conformity, not only with the difference of soly. between the latter as anhydrides and as hydrates, but also because of the pressures which the free CaO, in taking on H_2O, exercises upon those hydrates, upon any anhydrous compds. and in general upon any other more or less sol. component.

ROBERT S. POSMONTIER (*C. A.*)

43. Cement colors and their chemical testing. C. R. PLATZMANN. *Farben-Ztg.*, **26**, 1894–5 (1921).—Good cement and mortar colors should be mineral pigments, contain no free acids (SO_3, Cl) and H_2O-sol. substances, and be unaffected in color by CaO, cement, light, etc. The color strength may be detd. by the usual method of rubbing up the pigment with a definite amt. of ZnO. The relative coloring strength of an Fe_2O_3 pigment is dependent on its content of Fe_2O_3, Al_2O_3, and its loss on ignition. Black cement colors are either C or Mn blacks; ultramarine is best adapted for producing the blue colors; greens usually consist of Mg Al silicates and produce only dull green colors.

F. A. WERTZ (*C. A.*)

44. Effect of coloring materials on the strength of mortar. DUFF A. ABRAMS. *Eng. News-Record*, **86**, 721 (1921).—Compression tests were made on 1–2 mortar contg. a blue coloring material, red iron oxide up to 15% (in terms of wt. of cement), and carbon black up to 10%. The blue caused a pronounced increase in strength, the red a slight decrease, and the carbon black a material decrease.

J. C. WITT (*C. A.*)

PATENTS

45. Dental cements. S. SCHIFF. Brit. 161,868, June 16, 1920. Addition to 145, 052 (*C. A.*, **14**, 3134). Colloidal silicic acid, either in the sol condition or as hydrogel, acetogel, or alcogel, is added to certain classes of dental cements to increase their hardness and transparency. The cements in question are those composed of ZnO and a soln. of $ZnCl_2$ or $ZnSO_4$ or a phosphate, and those containing silicates or polysilicates with oxides, phosphates, borates, etc. of various metals and a soln. of phosphoric acid. The colloidal silicic acid may be added either to the soln. or to the solid ingredient of the cement, or to both, or it may be used alone with metallic oxides. (*C. A.*)

46. Slaking lime. E. R. SUTCLIFFE. Brit. 160,556, Dec. 22, 1919. Lime or the like is fed by a hopper into the first of a series of parallel cylinders through which it is propelled by stirring and conveying vanes. H_2O is sprayed upon the lime in the cylinder from a pipe parallel with the axis, and this cylinder is preferably provided with a H_2O jacket. The other cylinders are provided with steam jackets preferably of semicircular form so as to enclose the upper half only. The cylinders are connected at each end by cylinders forming vertical shafts which are provided alternately with segmental plates and segmental gratings so as to allow the material to be traversed in the desired path. A suitable construction is specified. (*C. A.*)

BOOK REVIEWS

Chemical Warfare. AMOS A. FRIES (Brigadier-General, C. W. S., U. S. A., Chief of Chemical Warfare Service) and CLARENCE J. WEST (Major, C. W. S. Reserve Corps, U. S. A., Nat'l. Research Council). pp. x + 445 and 121 figs. McGraw-Hill Book Co., New York, 1921. A very readable account of the history of the development of chemical warfare and its place in modern military tactics. It is difficult to understand how any American citizen could read this book and not become a strong advocate of the development of this branch of our Army to the point where knowledge of this terrible weapon is so complete that, in time of war, the defensive and offensive branches of the Service could be rapidly and efficiently expanded to a war footing. Not even the most ardent pacifist could object to a research program directed toward the development of the most efficient methods of protection against this frightfully efficient weapon, and an equal measure of preparedness to retaliate in kind will meet the approval of all advocates of a strong policy of national defense. A dollar spent in chemical warfare preparedness should produce more "pounds of preparedness" than could be secured by spending it on any other branch of the army; that is, chemical warfare preparedness, in peace time, is comparatively inexpensive.

The ceramic readers of this book will note with interest the adoption of the tunnel kiln for the activation of charcoal, and while the special field of the ceramic chemist does not touch very closely the problems of chemical warfare, there are some manufacturing problems where high temperatures and special ceramic bodies will find application. E. W. W.

American Society of Testing Materials: Standards. Issued triennially, 1921 Ed. pp. 890. Cloth $10; half-leather, $11.50. A. S. T. M., 1315 Spruce St., Philadelphia, Pa. This volume contains 160 methods of testing engineering materials. These methods, all of which have received the official approval of the Society, are distributed among the various materials as follows: 61 relating to steel and wrought iron; 7 to pig and cast iron and finished castings; 31 to non-ferrous metals; 18 to cement, lime, gypsum and clay products; 10 to preservative coatings and lubricants; 19 to road materials; 4 to coal and coke; 6 to timber and timber preservatives; 2 to rubber and 2 to miscellaneous subjects. Those of most interest to the ceramic industries cover: standard specifications for drain tile, paving brick, portland cement, natural cement, clay, sewer pipe, cement-concrete sewer pipe, building brick, gypsum plasters; standard definitions of terms relating to sewer pipe and clay refractories; standard specifications for making the following tests: (*a*) chemical analysis and physical and chemical properties of portland cement, (*b*) load test of refractory materials at high temperature, (*c*) chemical analysis of refractory materials including chrome ores and chrome brick, (*d*) fire tests of material in construction, (*e*) measurement of porosity and permanent volume changes in refractory materials, (*f*) softening point tests on fireclay brick, (*g*) determination of unit weight of aggregate for concrete; standard specifications for making and storing concrete specimens in the field;

recommended practice for laying sewer pipe; standard methods for mechanical analysis of sand and other fine materials; a variety of testing methods for road building materials.

Many, if not most of the methods described are the result of a gradual development based upon the practical experience of many engineers. Although approved by the Society in their present form, it is, of course, to be expected that many of these methods will undergo further changes and improvements as time goes on. Sources of error will be discovered and eliminated, methods will be simplified or refined according to the necessities of the case, and certain incongruities now present will be eliminated. It is to be hoped that the adoption of a method by the Society on the basis of the best engineering experience will eventually in all cases, be followed (if it cannot be preceded) by a thorough scientific examination of the method by some institution properly staffed and equipped for such work. The critical study of proposed testing methods is a task for the physicist and the chemist. The selection of a method for a given purpose, after the results of such a critical study are available, belongs to the province of the engineer. E. W. W.

Correction

57. The new Meurer enamel spraying process. ANON. *Sprechsaal*, **54**, 490–91 (1921), *This J.*, Vol. 4, No. 9, page 787, should read *Sprechsaal*, **45**, 139–140 (1921).

ACTIVITIES OF THE SOCIETY

Recent Actions of the Board of Trustees

November 10, 1921. It was voted that the American Ceramic Society should join the American Society for Testing Materials by payment of the dues of fifteen dollars.

It was voted that the Secretary should promote publicity by (*a*) the use of reprints, (*b*) addresses, and (*c*) press notices.

It was voted to consider the appointment of Miss Norah Binns as Assistant Secretary for the year 1922, provided she can be secured at a salary which will meet with the approval of the Board.

It was voted to authorize the Secretary to promote the establishment of Ceramic Trade Schools.

It was voted to recommend that provision be made for a standing "Service" Committee on Ceramic Education, the chairman to be a member of the Co-ordinating Service Council.

It was voted that the Society should have a booth and a "Day" at the Exposition of Chemical Industries.

It was voted to have an illustrative exhibit at the Exposition.

It was voted to instruct Secretary Binns to negotiate for the English and European excursion next summer, in the interests of the entire Society.

It was voted to provide stenographic service for the Divisional meetings at the annual meeting.

It was voted to encourage exhibits at the annual meeting.

Recent Action of the Society

November 16, 1921. One hundred thirty-one votes were cast on the Proposed Amendments to the Constitution and By-Laws; one hundred twenty-eight affirmative, three negative. The amendments are carried and go into immediate effect. The articles and sections as amended are here given in full.

CONSTITUTION

Article VI

Standing Committees

(1) The following Standing Committees shall be appointed annually by the board of Trustees:

1. Rules
2. Publications

3. Membership
4. Standards
5. Sections and Divisions
6. Papers and Programs
7. Research
8. Geological Surveys
9. Data
10. A Coördinating Service Council.

The chairman of each committee shall be appointed by the Board of Trustees.

(2) The Committee on Rules shall consist of five members in addition to the chairmen of the Rules Committees of the divisions having such committees. It shall receive all recommendations relating to changes of Constitution and By-Laws and shall report upon the same to the Secretary for transmission to the Society. It shall have power to propose changes in the Rules of the Society.

(3) The Committee on Publications shall consist of the Editor and four members. The duties of the Editor and Committee on Publications are defined under Article X on Publications.

(4) The Committee on Membership shall consist of at least five members in addition to the chairmen of Membership Committees of the divisions having such committees, and shall have power to appoint sub-committees. Its function shall be to undertake systematically the enlargement of the membership of the Society amongst those interested in the ceramic and allied industries.

(5) The Committee on Standards shall consist of a chairman appointed by the Board of Trustees and topic groups as follows:

Group on Definitions, consisting of three members appointed by the Board of Trustees.

Group on Raw Material Specifications, consisting of three members appointed by the Board of Trustees.

Group on Standardization of Test, consisting of one member elected by each Division.

Group on Standardization of Products, consisting of one member elected by each Division.

(6) The divisional Standardization Committees shall be appointed in and by their respective divisions. Their functions shall be the preparation of test and specifications for the materials and products of their respective branches of ceramic industry. Each shall be responsible to its own division, but all reports, resolutions or recommendations that are to be printed or generally distributed shall be approved by the Committee on Standards before publication.

(7) The function of the Committee on Standards shall be to prepare or have prepared tests and specifications for ceramic materials and products and to submit to the Board of Trustees written reports, resolutions and recommendations relating thereto. The Committee may report at any regular

meeting of the Society. For adoption, these reports, resolutions, and recommendations must be submitted in printed form to the members of the Society at least six months before a vote may be taken, during which time any amendments, changes, or corrections, suggested by any member may, with the approval of the Committee, be incorporated. The reports, resolutions, and recommendations as amended shall then be submitted by letter ballot to the voting members. A two-thirds vote shall be required for adoption, and the polls shall close 60 days after distribution of the ballot.

(8) The Committee on Sections and Divisions shall consist of five members in addition to the chairmen of the Divisions. Its duties shall be to promote the organization and welfare of Local Sections, Student Branches, and Divisions.

(9) The Committee on Papers and Programs shall consist of the secretaries of the Divisions, the Secretary of the Society, and such other persons as the Board of Trustees may deem advisable. Its duties shall be to procure papers and discussions for the meetings and publications of the Society. The Committee may require an abstract of any paper submitted before placing it upon a program.

(10) The Committee on Research shall consist of a chairman and three members appointed by the Board of Trustees, and one member elected by each Division. Its duties shall be to organize and encourage scientific investigations pertaining to the ceramic and related industries, especially those investigations which will stimulate the development of our national industries and resources. It shall be empowered to coöperate with similar committees of other scientific societies and with Government bureaus.

(11) The committee on Geological Surveys will coöperate with National and State Geological Surveys and Associations in planning laboratory and plant investigations instituted by them, and interpreting data. This committee shall consist of a chairman and four members appointed by the Board of Trustees.

(12) The Committee on Data shall arrange symposiums and prepare for publication monographs, bibliographies, statistics, etc. This committee shall consist of a chairman appointed by the Board of Trustees and one member elected by each Division.

(13) The Coördinating Service Council shall consist of the General Secretary, ex-officio chairman, and the chairmen of the Committees on research, Standards, Geological Surveys, and Data. The Council shall have general supervision of the work of these committees, for the purpose of coordinating their work within the Society and with the work of other organizations on ceramic topics and problems.

BY-LAWS

Section VIII

(1) The Board of Trustees shall appoint such special committees as may seem necessary for the proper conduct of the affairs of the Society.

(2) All Special Coöperative Committees shall be appointed only on nomination of the Coördinating Service Council.

Section IX

The Board of Trustees shall have power to make any rules not inconsistent with the constitution and By-Laws for the conduct of its business.

COÖRDINATING SERVICE COUNCIL

General Secretary, ex-officio Chairman
Four members, appointed by Board of Trustees to serve as Chairmen of Committees 1 to 4, inclusive

		Committee Members	Coöperation with other organizations
1. Committee on Research	Pure Science Applied and Industrial Science	3 members appointed by Board 1 member chosen by each Division	National Research Council (Div. Chemistry and Chemical Technology, Div. Research Extension, and Div. Engineering) Federal Bureaus Semi-Public, Commercial, and Industrial Laboratories Universities Trade and Technical Associations
2. Committee on Standards	(*a*) Definitions (*b*) Raw Materials Specifications (*c*) Standardization of Tests (*d*) Standardization of Products	(*a*) 3 members appointed by Board (*b*) 3 members appointed by Board (*c*) 1 member chosen by each Division (*d*) 1 member chosen by each Division	American Society for Testing Materials (Committees C-1 to C-11, inclusive, D-4, and D-9) Foreign Ceramic Societies Trade and Technical Associations Federal Bureaus American Engineering Standards Committee, etc.
3. Committee on Geological Surveys	Advisory on Tests and Interpretation of Data	4 members appointed by Board	National Research Council (Div. Geology and Geography) U. S. and State Geological Surveys
4. Committee on Data	(*a*) Symposiums (*b*) Monographs (*c*) Bibliographies (*d*) Statistics	1 member chosen by each Division	National Research Council Trade and Technical Associations Federal Bureaus Commercial Laboratories Universities

New Members Received during November, 1921

Resident Associate

Baker, Earl B., 22 Sixteenth Ave., Columbus, Ohio, U. S. Bureau of Mines.

Crow, Waller, 2828 Smallman St., Pittsburgh, Pa., Secretary-Treasurer, Schaffner Engineering and Equipment Co.

Funkhouser, E. N., Hagerstown, Md., Secretary, Maryland Glass Sand Co.
Hartmann, Miner L., 3006 McKoon Ave., Niagara Falls, N. Y., Director, Research Laboratory, The Carborundum Co.
Keese, A. W., 1312 E. 112th St., Cleveland, Ohio, General Superintendent, Collinwood Shale Brick and Supply Co.
Lee, P. William, 395 Fourteenth Ave., Columbus, Ohio.
Richeux, William A., 343–347 Cortlandt St., Belleville, N. J., General Manager, "Isolantite."
Wilson, Della F., 612 Howard Place, Madison, Wis., Instructor, University of Wisconsin.
Zahm, Robert Charles, 272 East 11th Ave., Columbus, Ohio, U. S. Bureau of Mines.

Foreign Associate

Endell, Kurd, Berlin Steglitz, Breitestr. 3, Germany.

Corporation

Clinchfield Products Corporation, 350 Madison Ave., New York City.
Proctor & Schwartz, Inc., Seventh St. and Tabor Rd., Philadelphia, Pa.

Report of the Nominating Committee for 1922-23

TO THE VOTING MEMBERS OF THE AMERICAN CERAMIC SOCIETY:

The Nominating Committee makes the following report on nominations for officers for the year 1922–1923:

President—F. H. Riddle,
Champion Porcelain Co., Detroit, Mich.
Vice President—E. W. Tillotson,
Mellon Institute, Pittsburgh, Pa.
Treasurer—R. K. Hursh,
University of Illinois, Urbana, Ill.
Trustee—B. E. Salisbury,
Onondaga Pottery, Syracuse, N. Y

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Journal of the American Ceramic Society

Volume 4

Original Papers
Ceramic Abstracts
and
Activities of the Society

Edward W. Washburn, Editor

This Society is not, as an organization, responsible for the statements of facts or opinions expressed in these papers and discussions

Published for the Society, under the supervision of the Committee on Publications:

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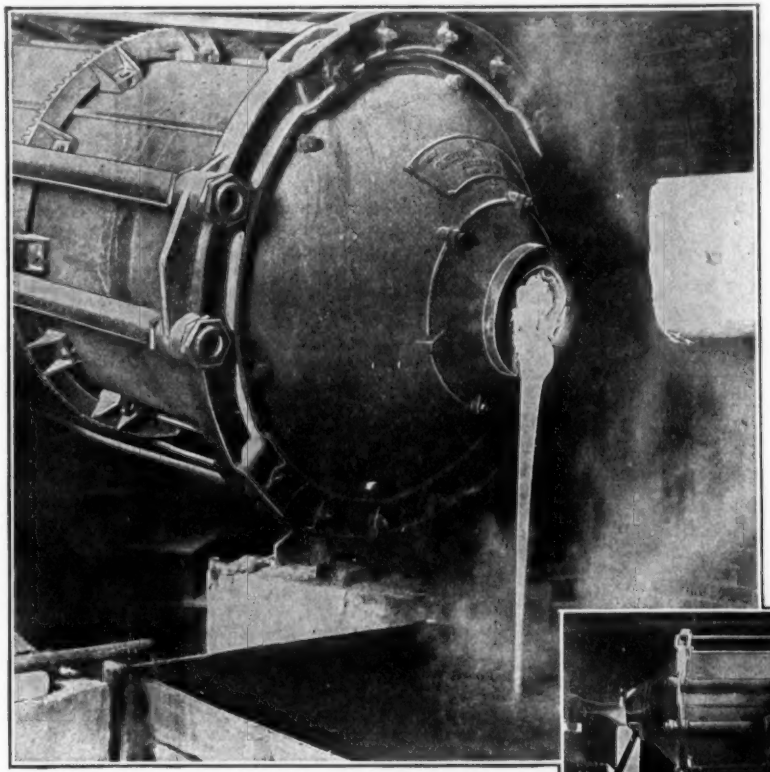

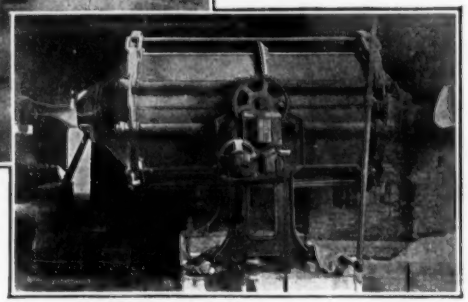

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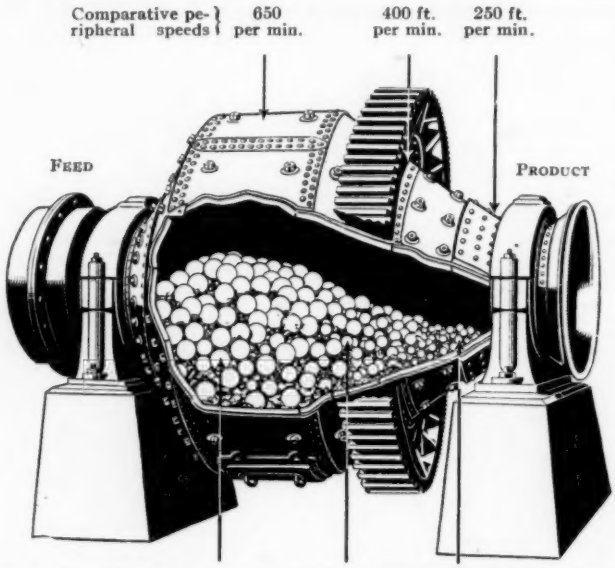

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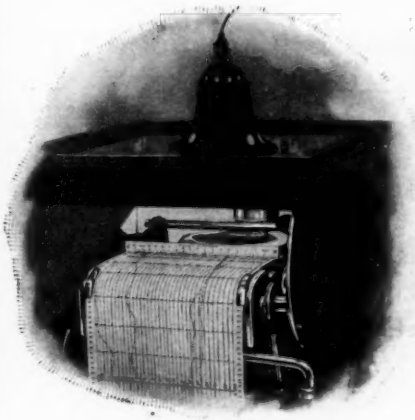

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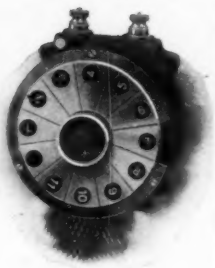

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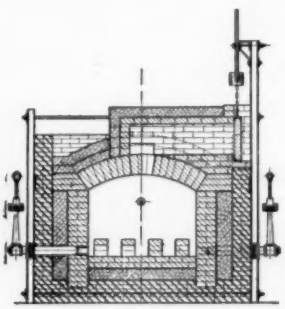

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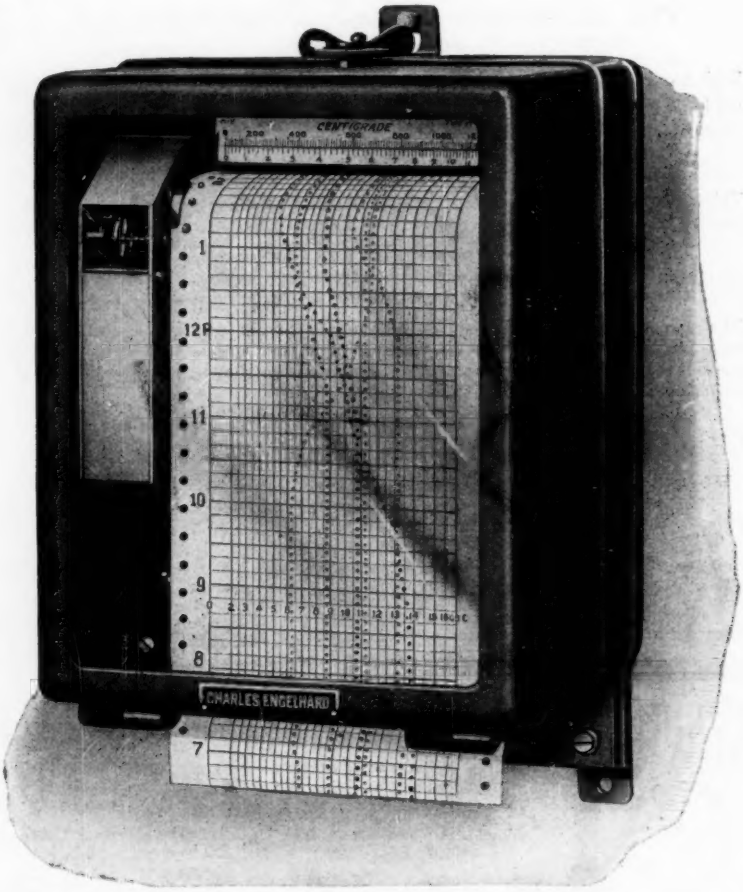

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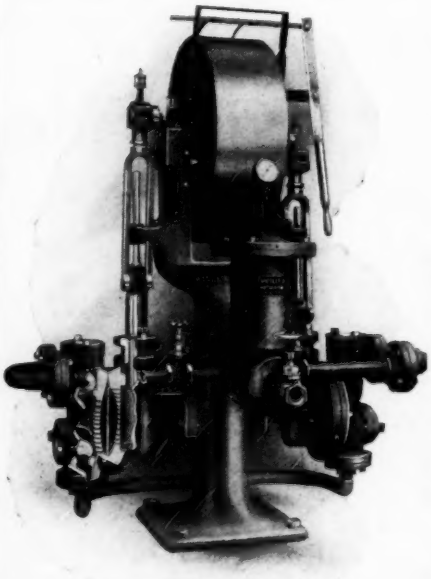

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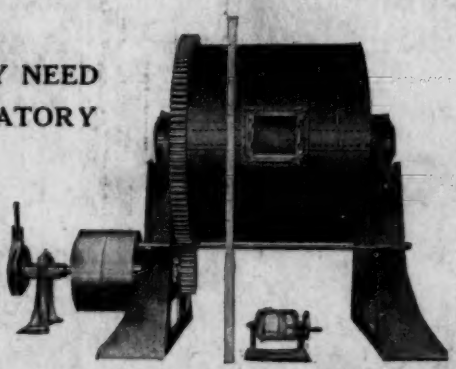

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